Appendix A

HSPF Model

Enterococci Bacteria Simulation

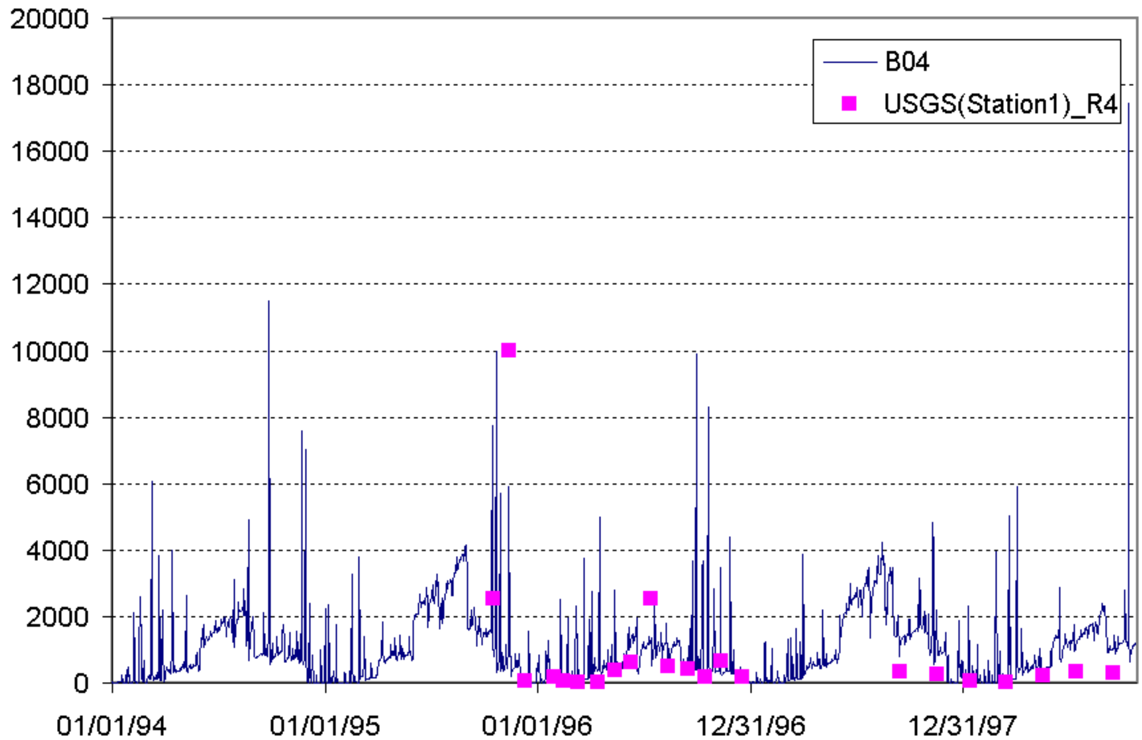
Time-series Calibration Results
(01/01/1994 to 10/29/1998)

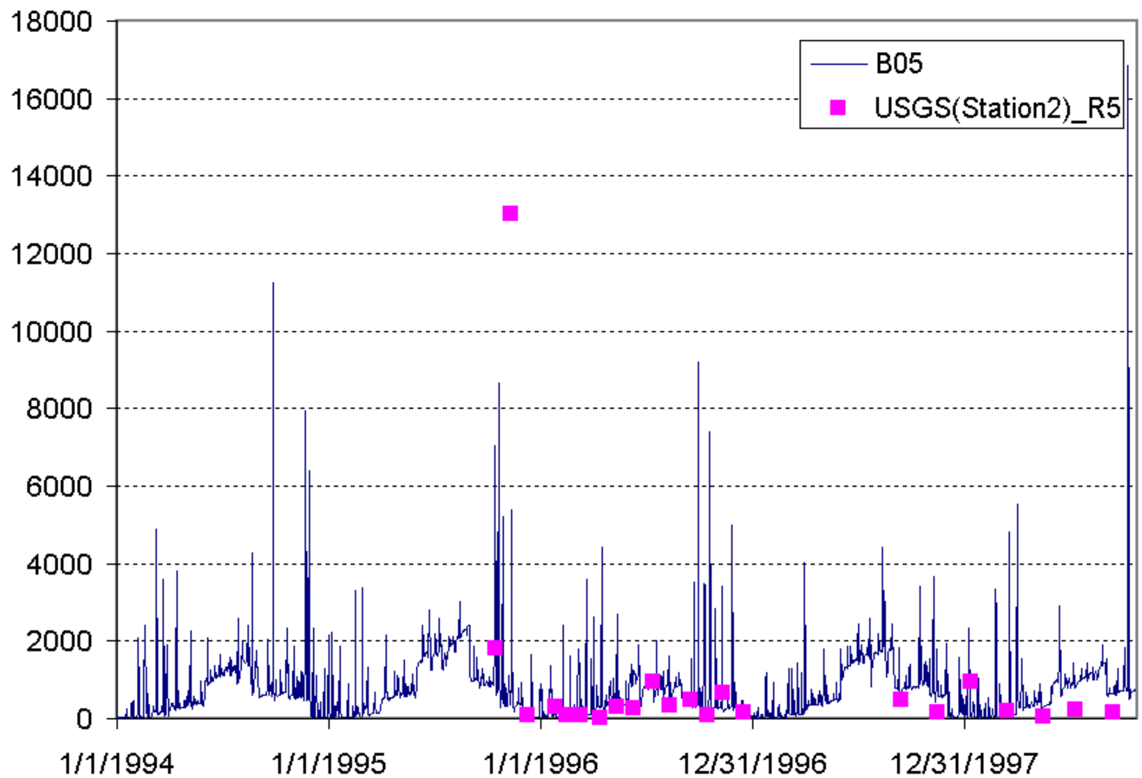
Brandywine Creek Watershed

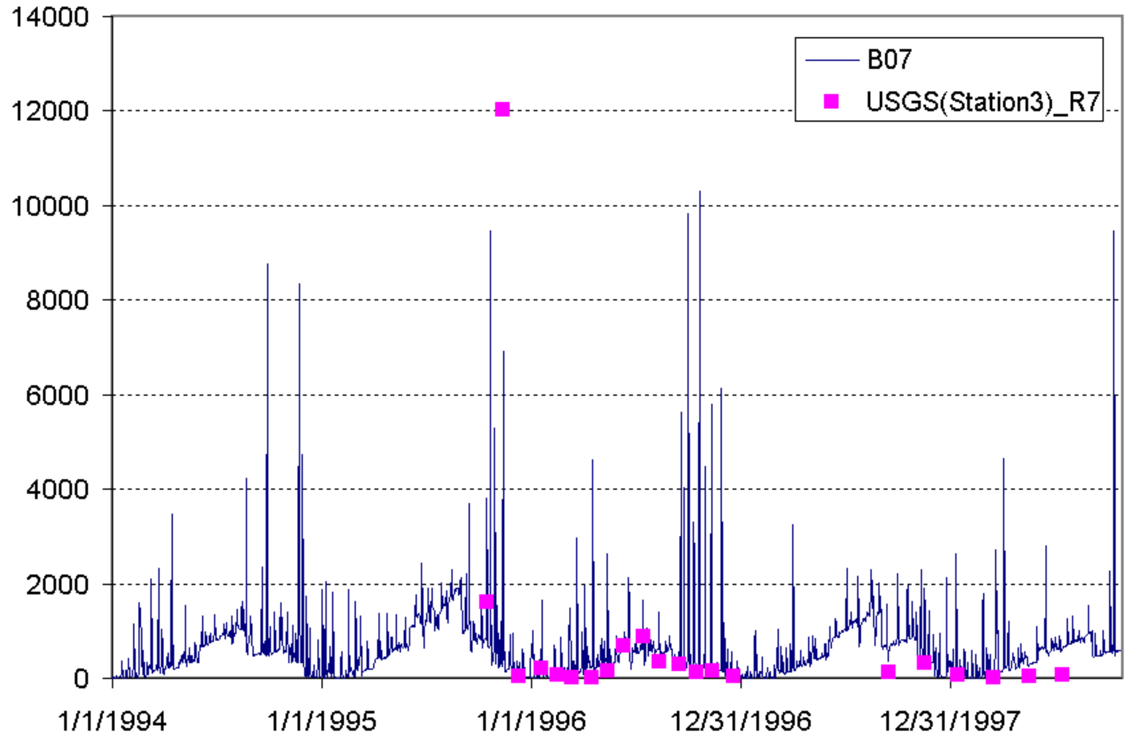
(y-axis units are cfu/100 mL)

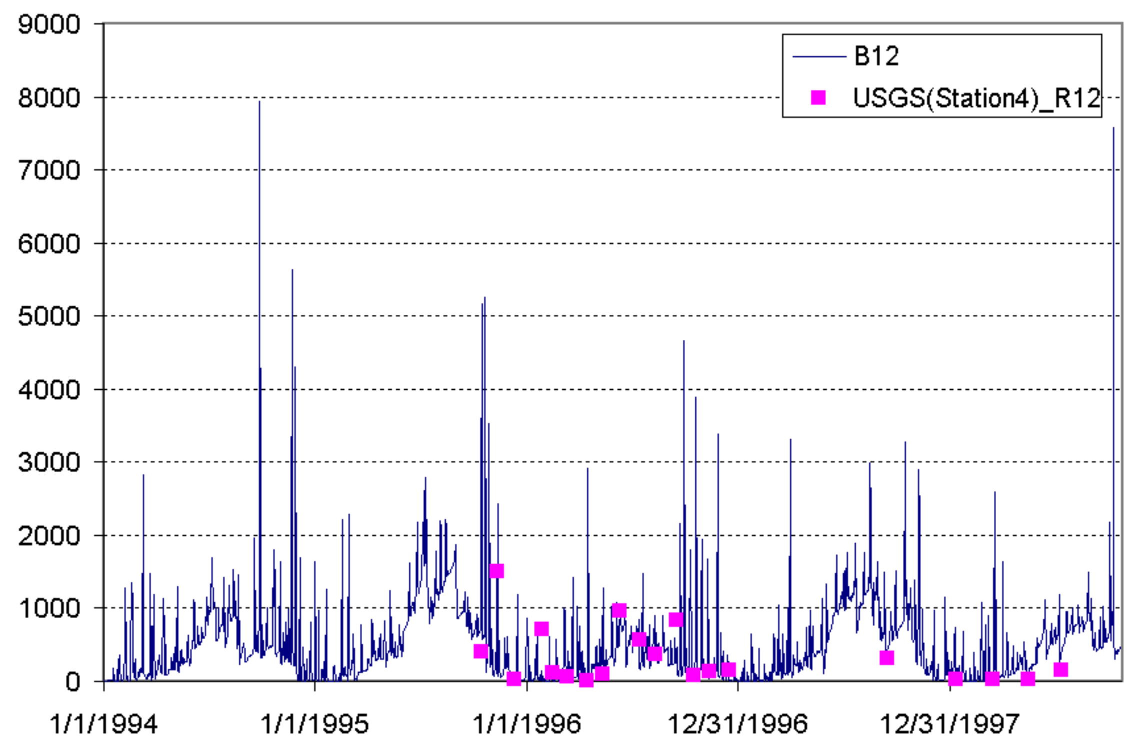
Model results are daily average.

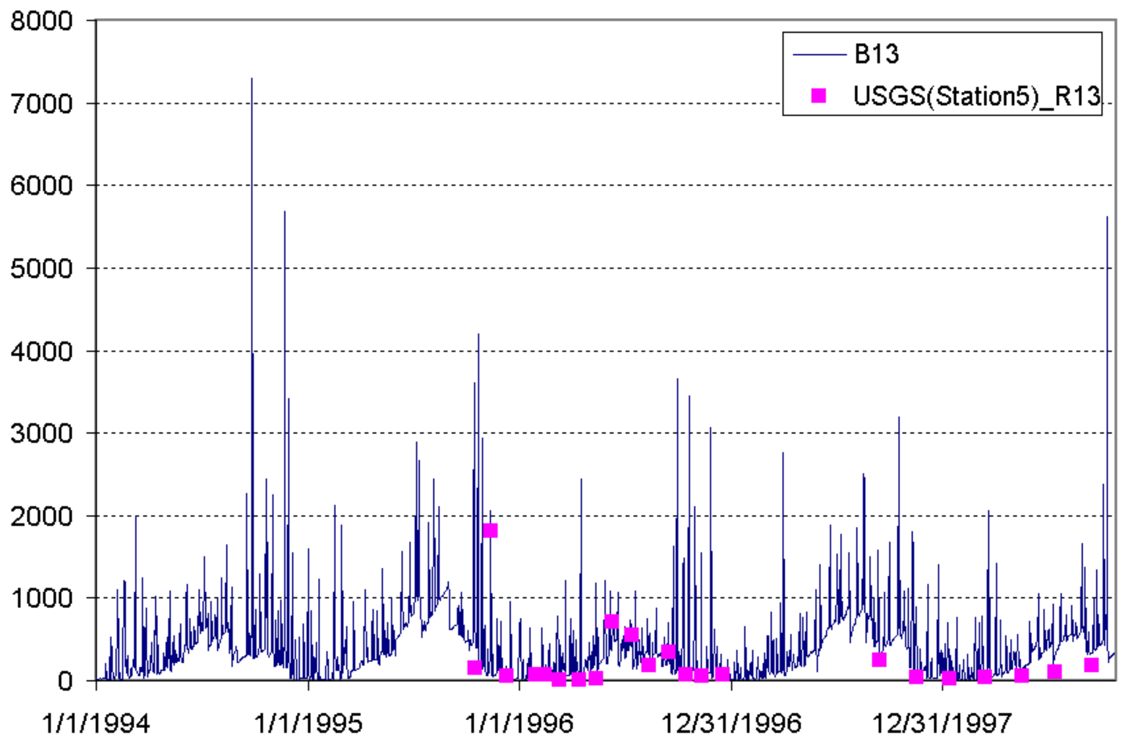
Field observations are grab samples (approximately monthly).

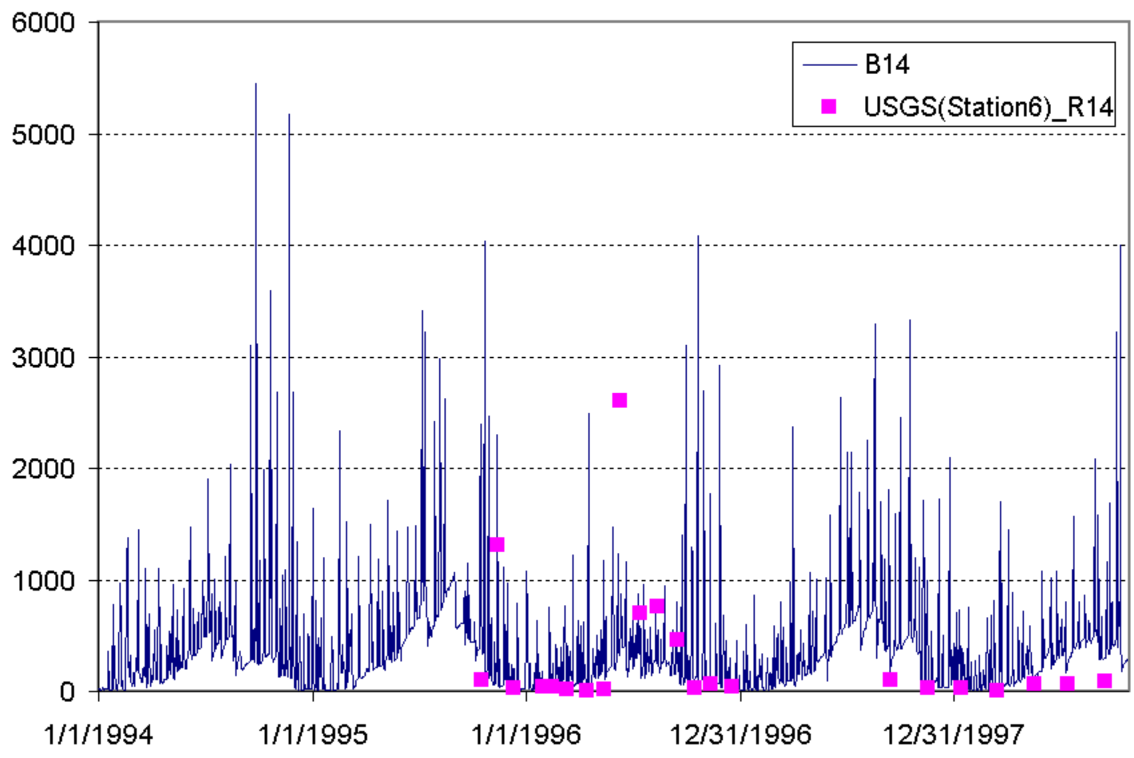

20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
01/01/94
01/01/95
01/01/96
12/31/96
12/31/97
B04
USGS(Station1)_R4

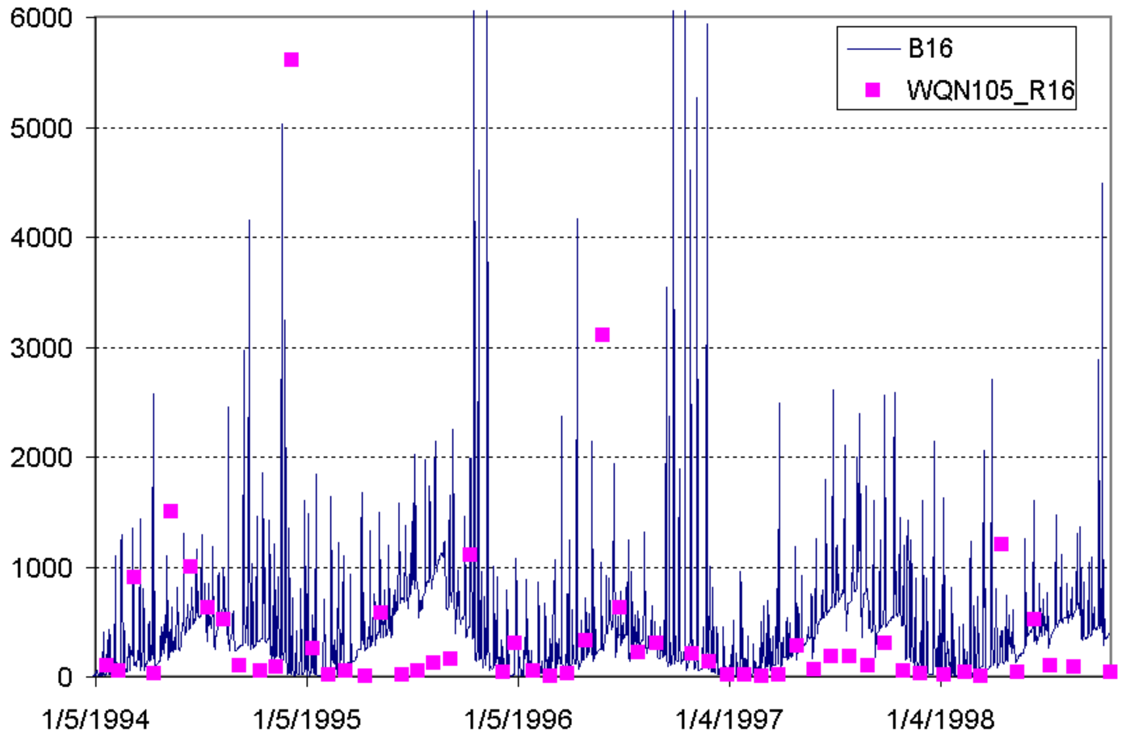

18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1/1/1994
1/1/1995
1/1/1996
12/31/1996
12/31/1997
B05
USGS(Station2)_R5

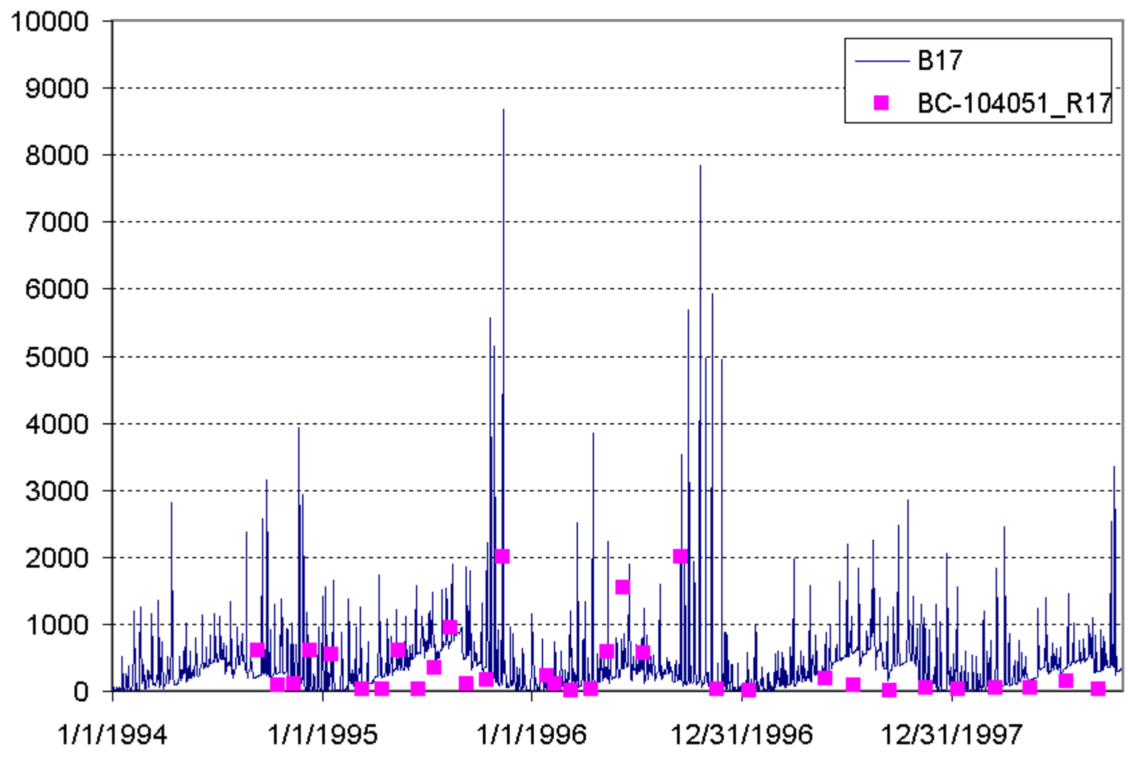

14000
12000
10000
8000
6000
4000
2000
0
1/1/1994
1/1/1995
1/1/1996
12/31/1996
12/31/1997
B07
USGS(Station3)_R7

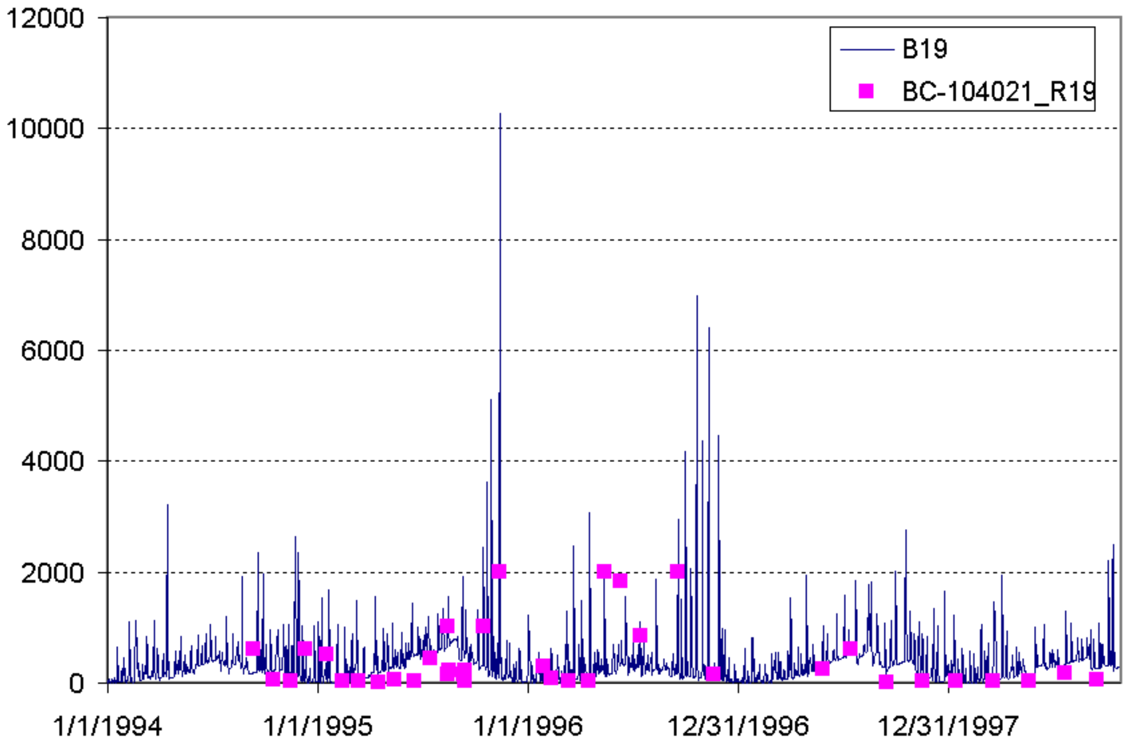

9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1/1/1994
1/1/1995
1/1/1996
12/31/1996
12/31/1997
B12
USGS(Station4)_R12


8000
7000
6000
5000
4000
3000
2000
1000
0
1/1/1994
1/1/1995
1/1/1996
12/31/1996
12/31/1997
B13
USGS(Station5)_R13

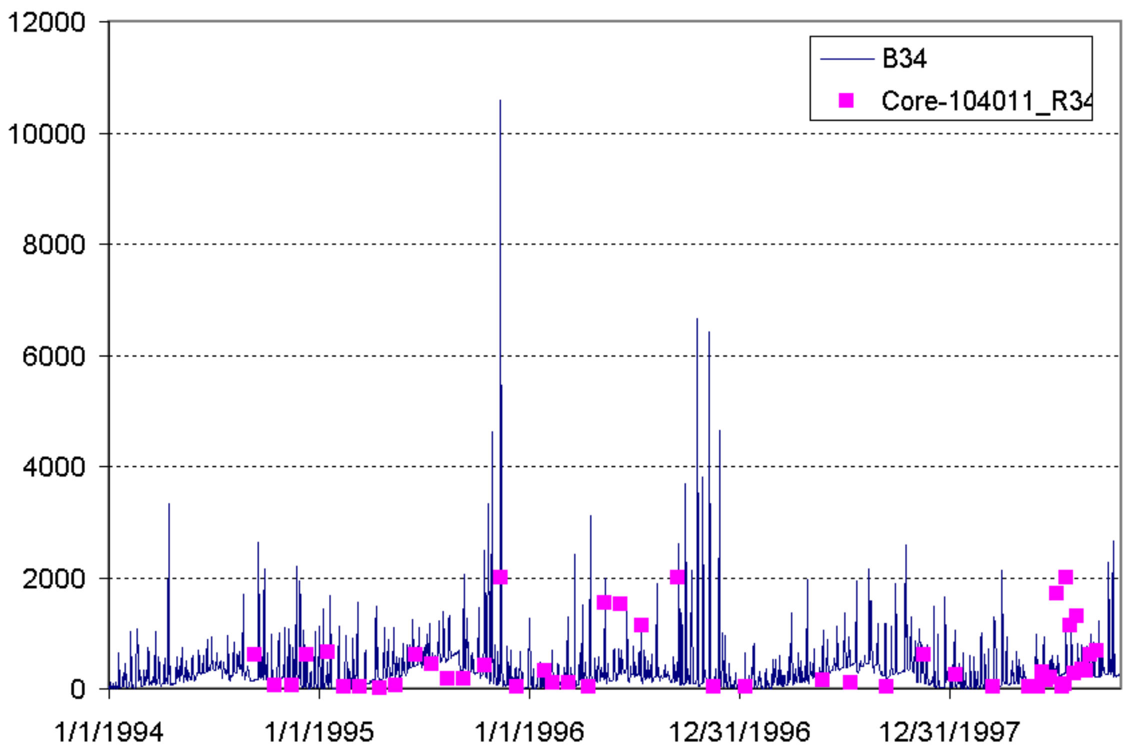

6000
5000
4000
3000
2000
1000
0
1/1/1994
1/1/1995
1/1/1996
12/31/1996
12/31/1997
B14
USGS(Station6)_R14


6000
5000
4000
3000
2000
1000
0
1/5/1994
1/5/1995
1/5/1996
1/4/1997
1/4/1998
B16
WQN105_R16


10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1/1/1994
1/1/1995
1/1/1996
12/31/1996
12/31/1997
B17
BC-104051_R17



12000
10000
8000
6000
4000
2000
0
1/1/1994
1/1/1995
1/1/1996
12/31/1996
12/31/1997
B19
BC-104021_R19



12000
10000
8000
6000
4000
2000
0
1/1/1994
1/1/1995
1/1/1996
12/31/1996
12/31/1997
B34
Core-104011_R34

Appendix B

HSPF Model

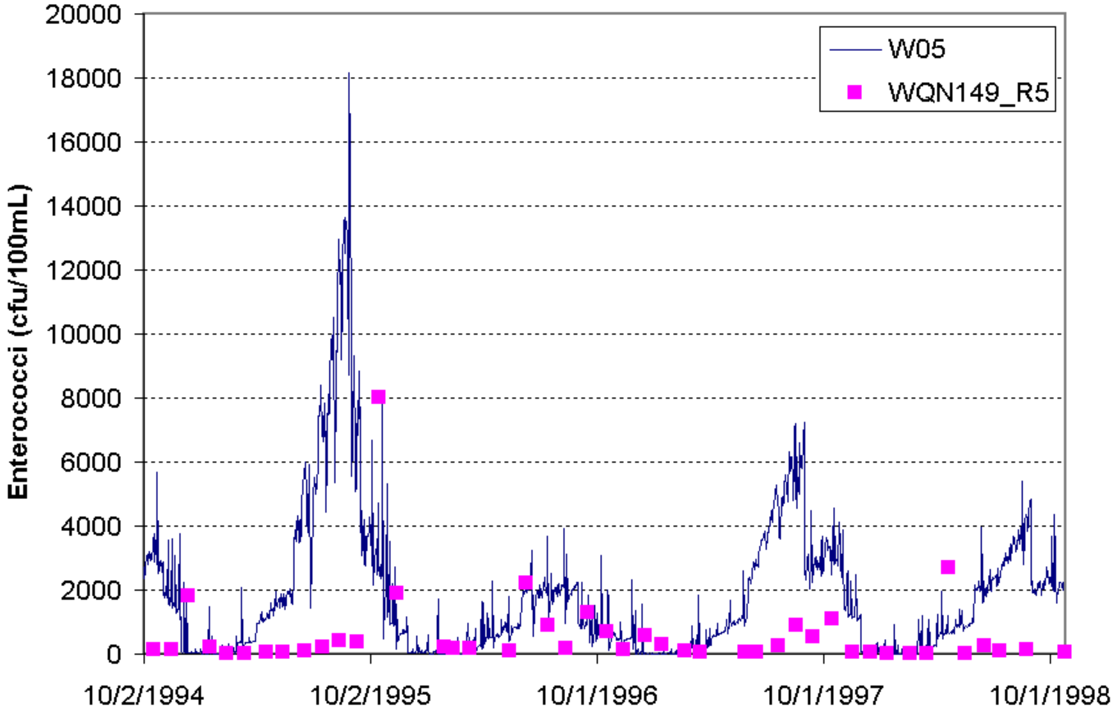
Enterococci Bacteria Simulation

Time-series Calibration Results
(1/1/1994 to 10/29/1998)

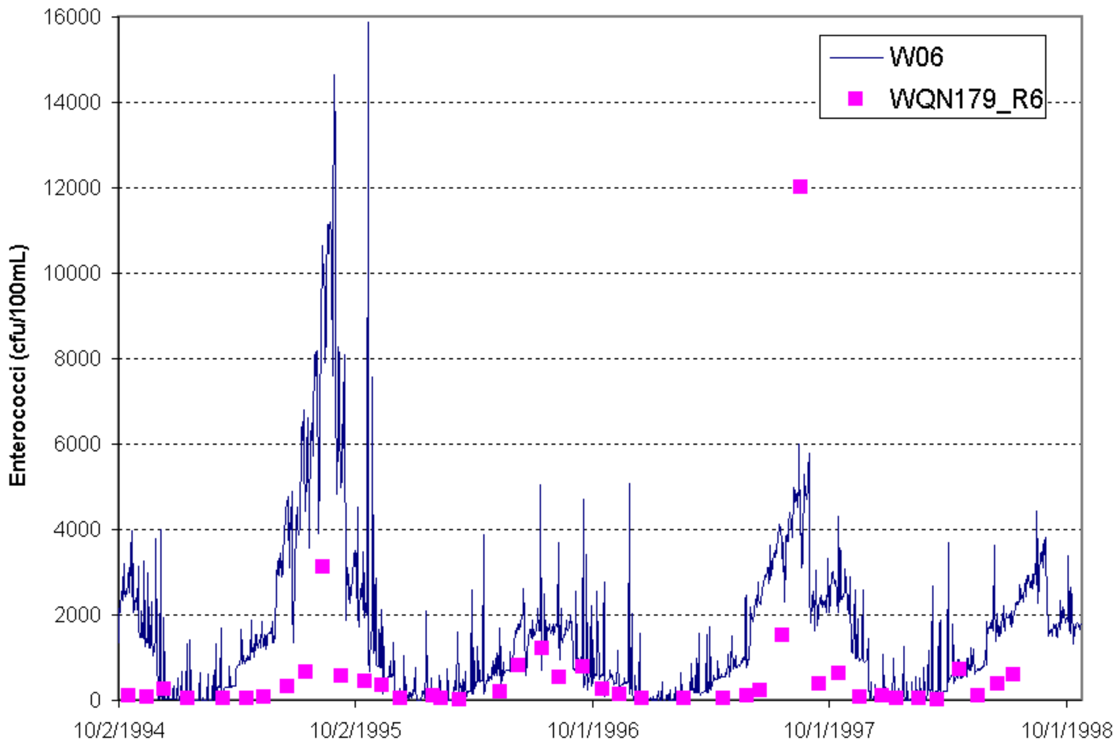
White Clay Creek Watershed

Model results are daily average

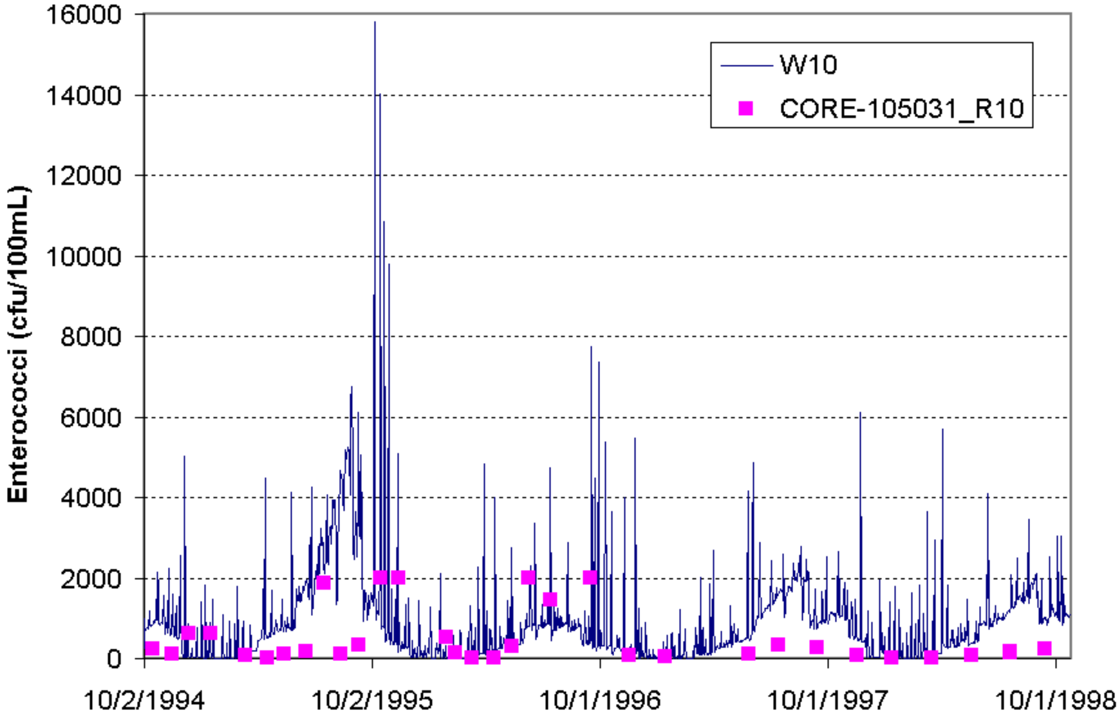
Field observations are grab samples (approximately monthly)



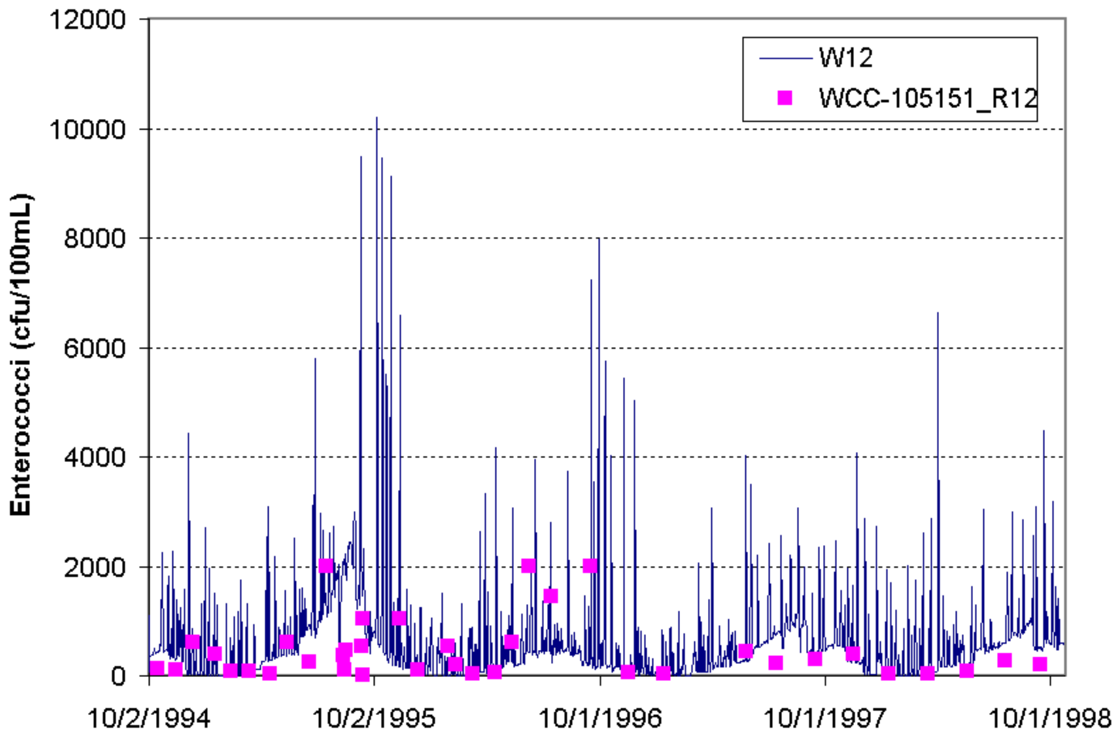
W05
WQN149_R5
Enterococci (cfu/100mL)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998



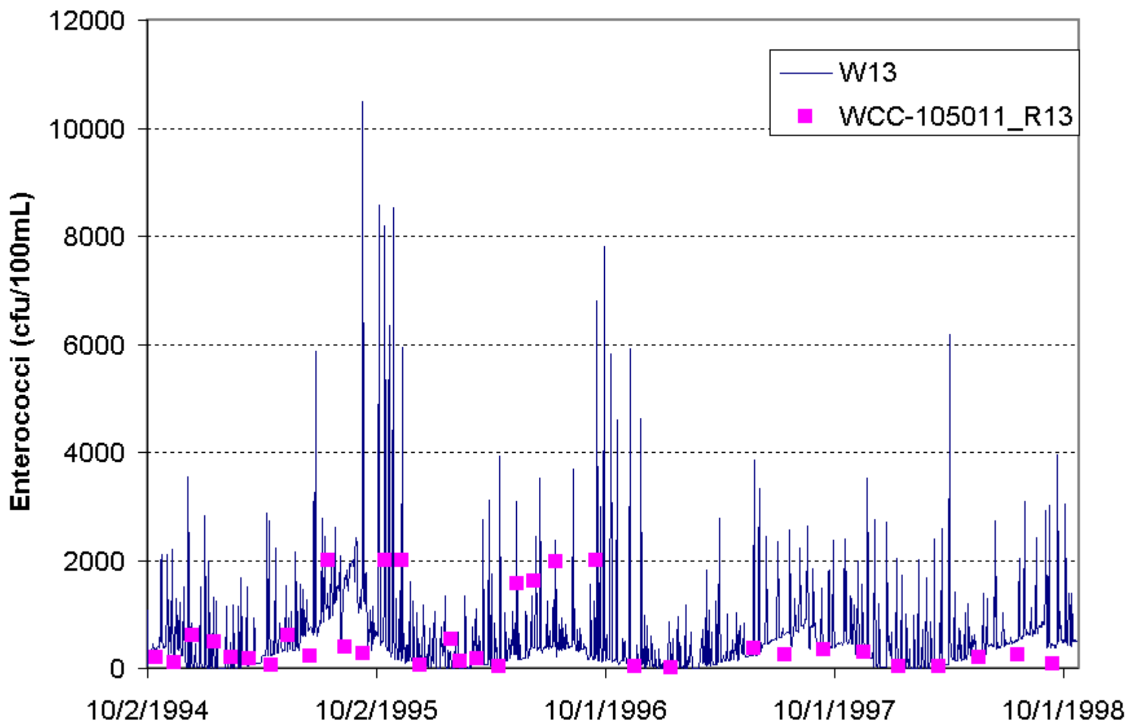
W06
WQN179_R6
Enterococci (cfu/100mL)
16000
14000
12000
10000
8000
6000
4000
2000
0
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998



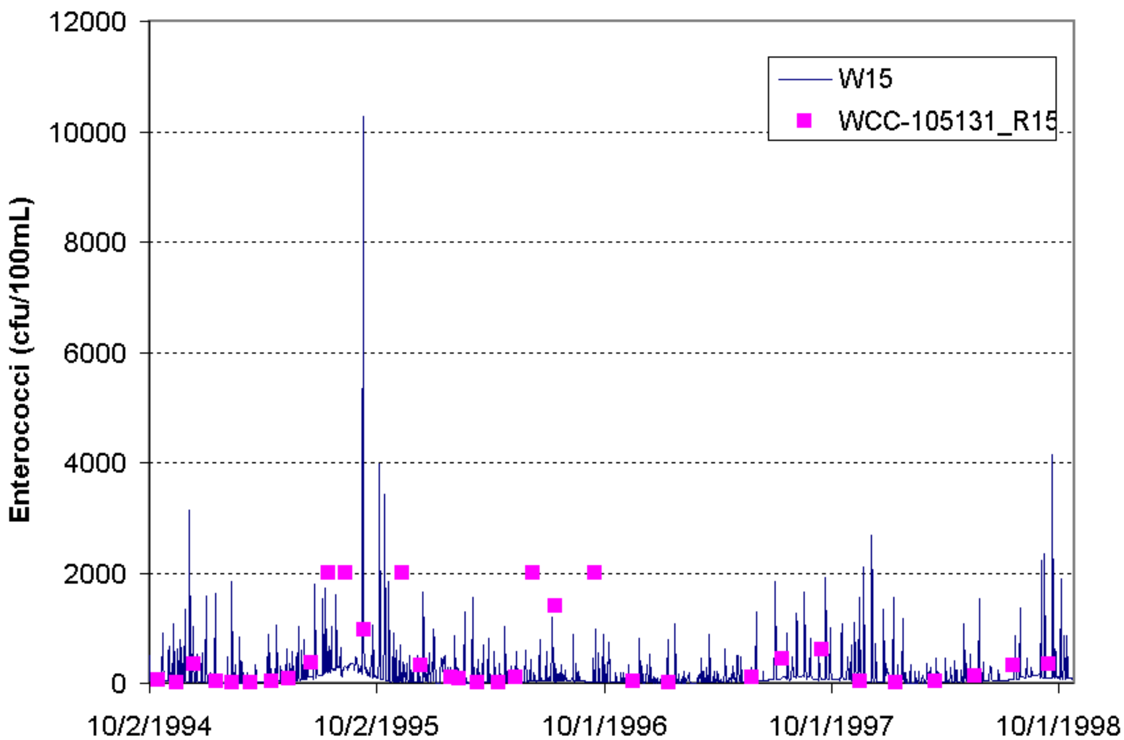
W10
CORE-105031_R10
Enterococci (cfu/100mL)
16000
14000
12000
10000
8000
6000
4000
2000
0
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998



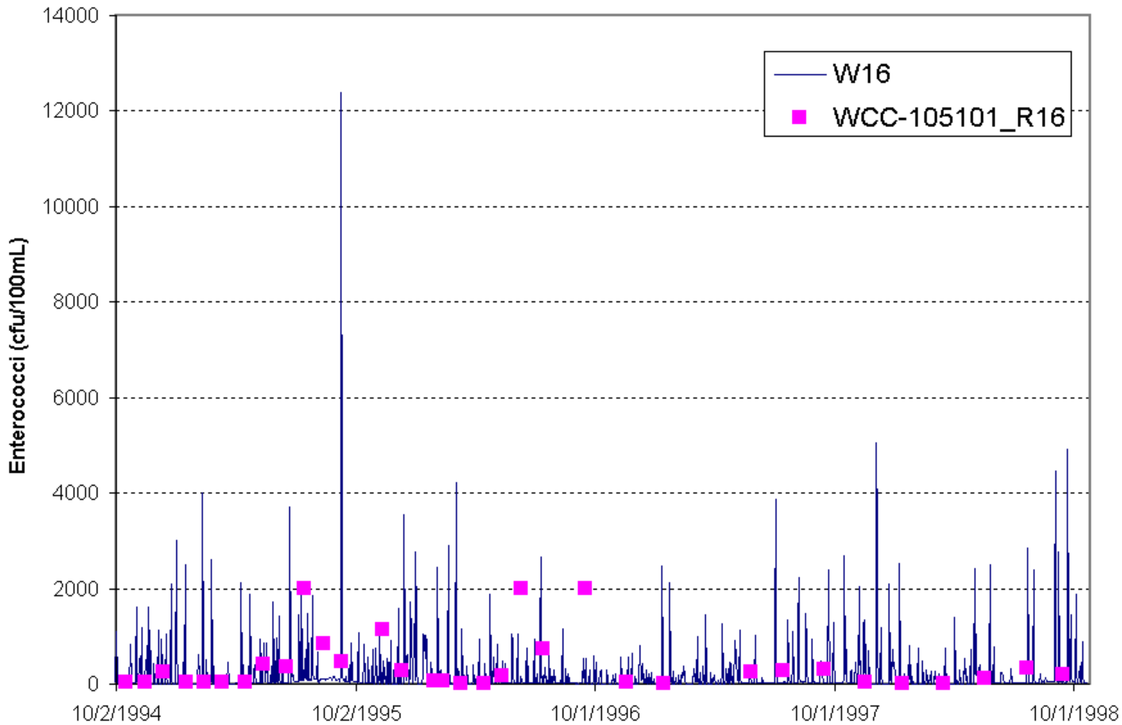
W12
WCC-105151_R12
Enterococci (cfu/100mL)
12000
10000
8000
6000
4000
2000
0
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998



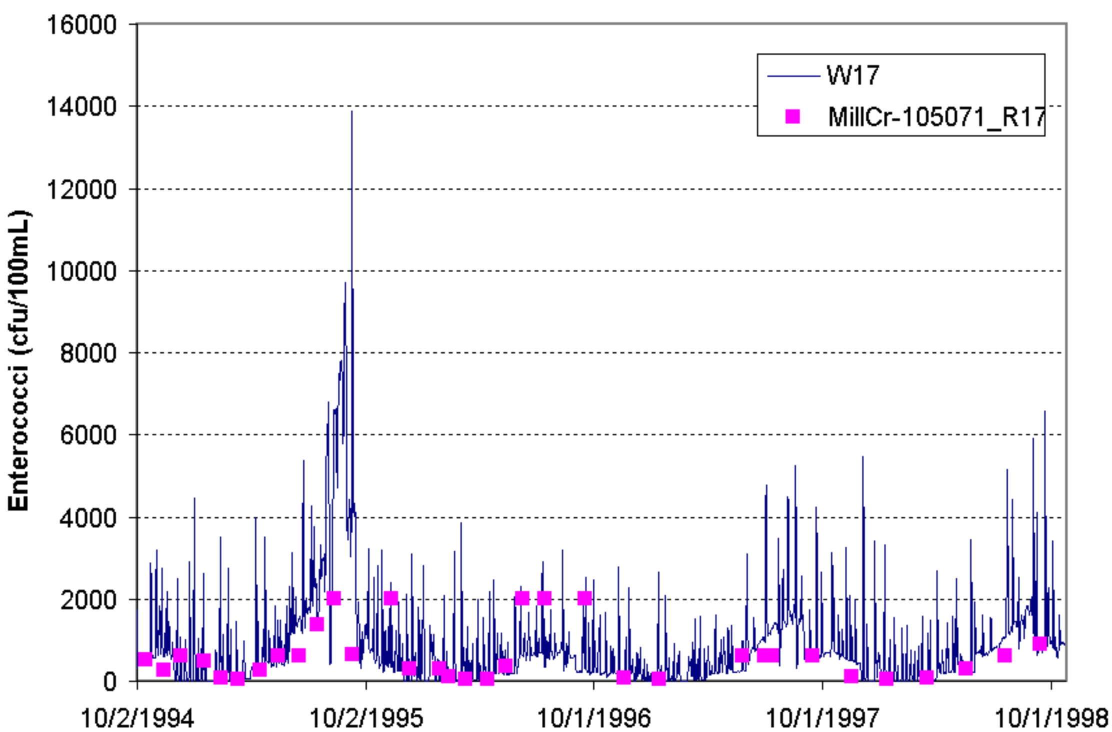
12000
10000
8000
6000
4000
2000
0
Enterococci (cfu/100mL)
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998
W13
WCC-105011_R13



12000
10000
8000
6000
4000
2000
0
Enterococci (cfu/100mL)
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998
W15
WCC-105131_R15



14000
12000
10000
8000
6000
4000
2000
0
Enterococci (cfu/100mL)
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998
W16
WCC-105101_R16



16000
14000
12000
10000
8000
6000
4000
2000
0
Enterococci (cfu/100mL)
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998
W17
MillCr-105071_R17

Appendix C

HSPF Model

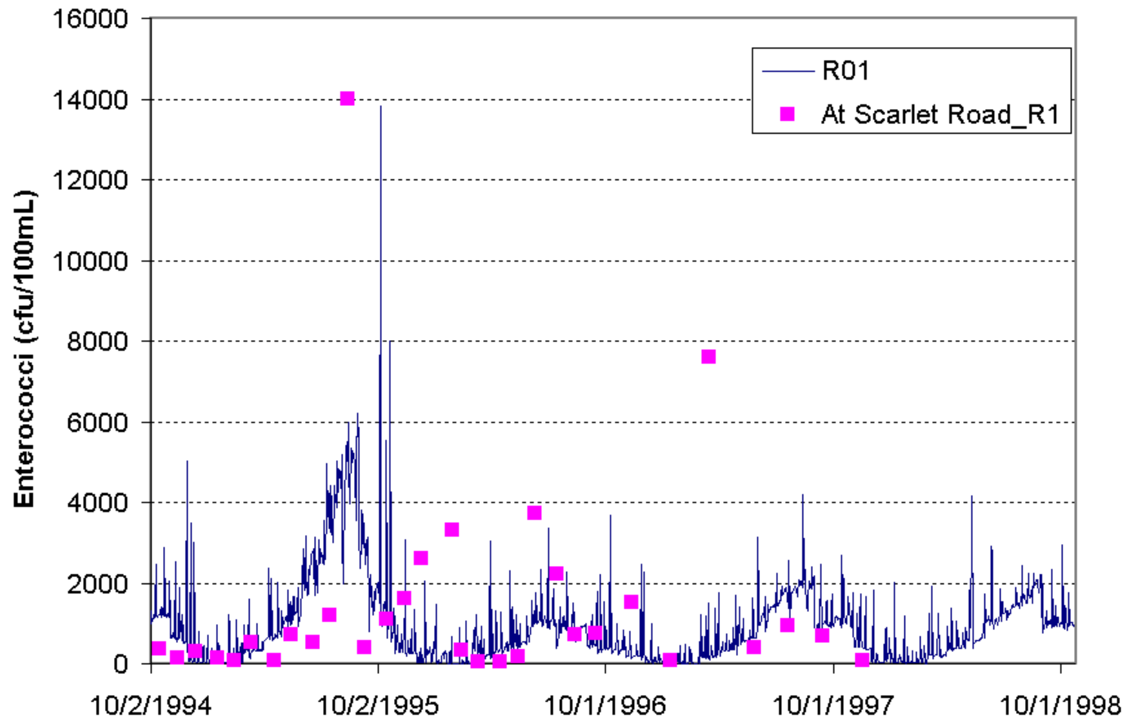
Enterococci Bacteria Simulation

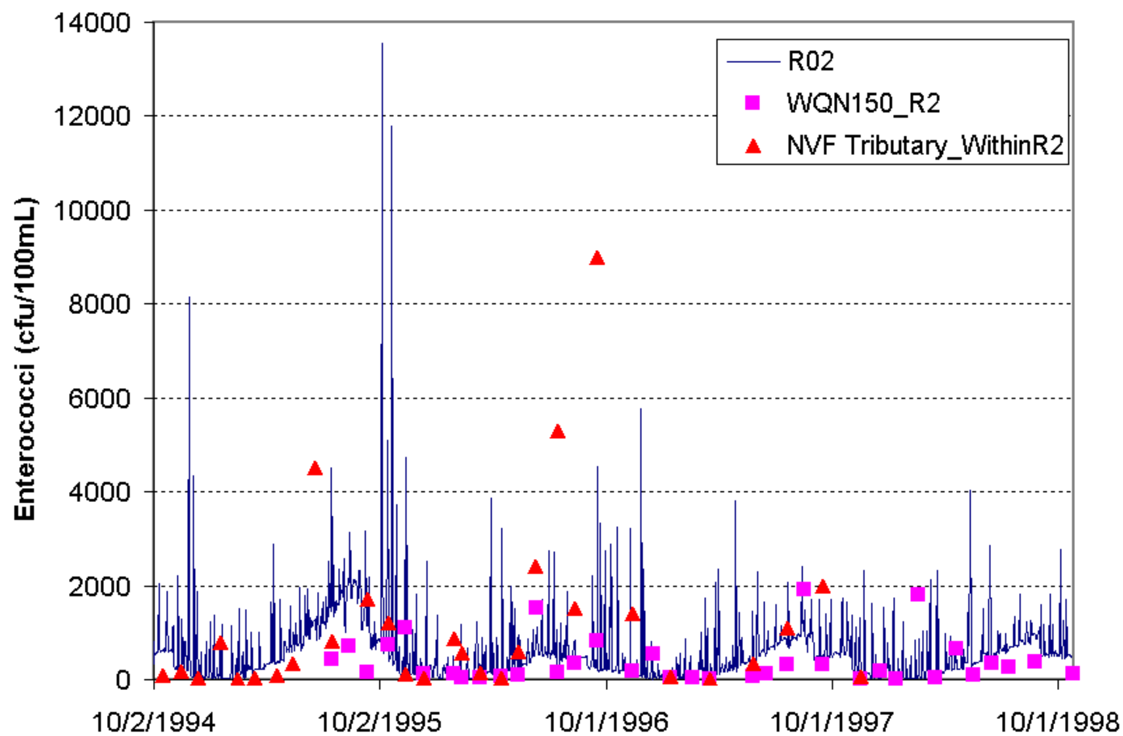
Time-series Calibration Results
(1/1/1994 to 10/29/1998)

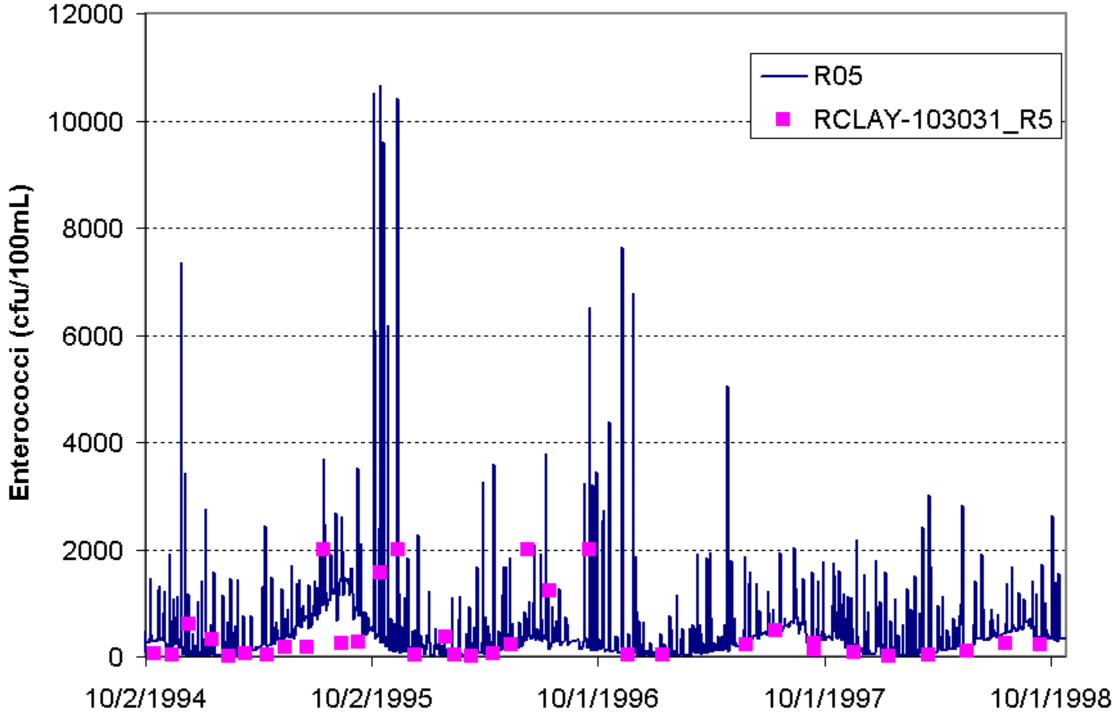
Red Clay Creek Watershed

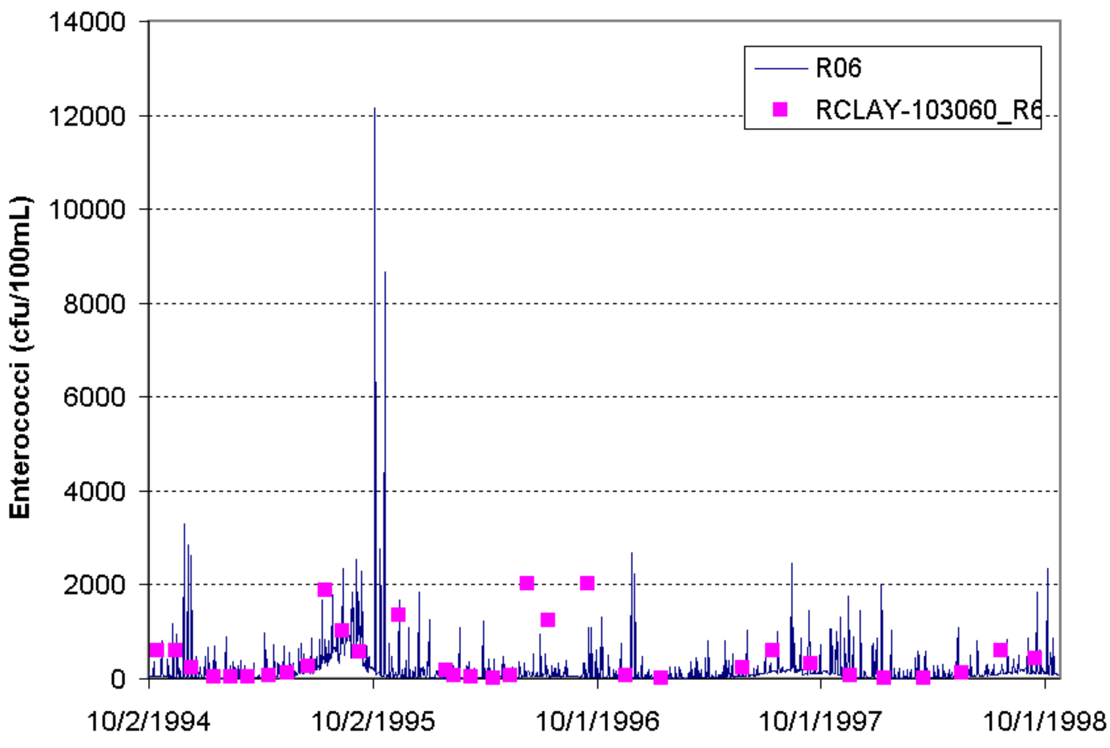
Model results are daily average

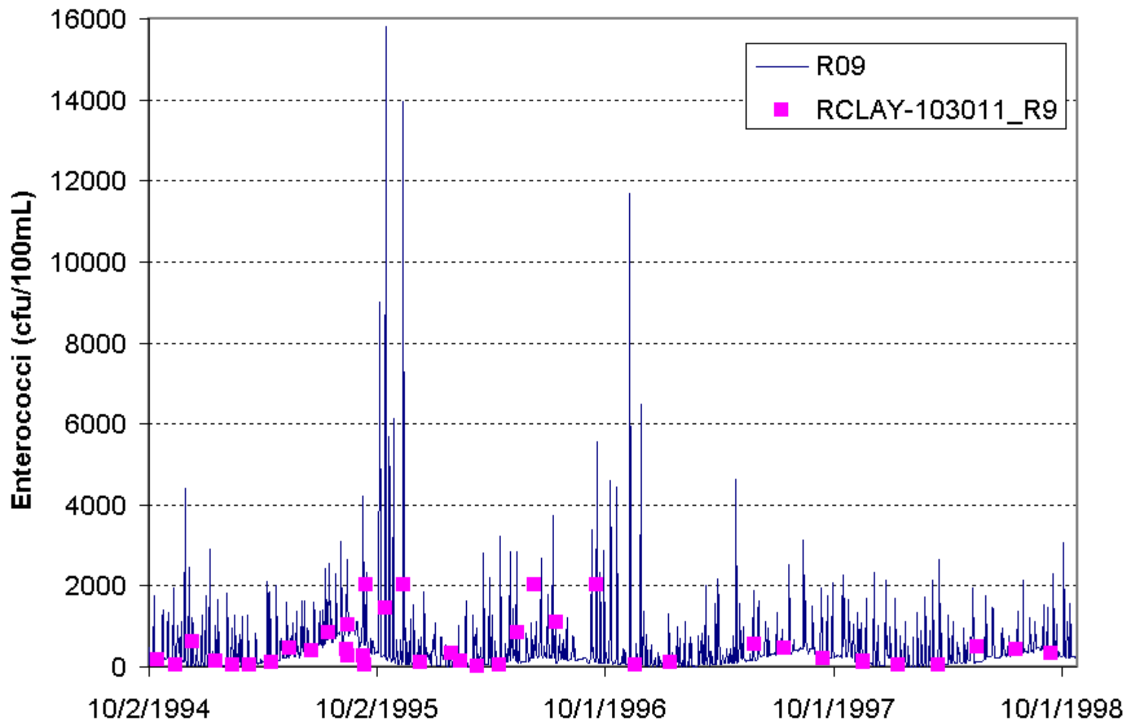
Field observations are grab samples (approximately monthly)


16000
14000
12000
10000
8000
6000
4000
2000
0
Enterococci (cfu/100mL)
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998
R01
At Scarlet Road_R1


14000
12000
10000
8000
6000
4000
2000
0
Enterococci (cfu/100mL)
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998
R02
WQN150_R2
NVF Tributary_WithinR2


R05
RCLAY-103031_R5
Enterococci (cfu/100mL)
12000
10000
8000
6000
4000
2000
0
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998


R06
RCLAY-103060_R6
Enterococci (cfu/100mL)
14000
12000
10000
8000
6000
4000
2000
0
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998



Enterococci (cfu/100mL)
16000
14000
12000
10000
8000
6000
4000
2000
0
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998
R09
RCLAY-103011_R9

Appendix D

HSPF Model

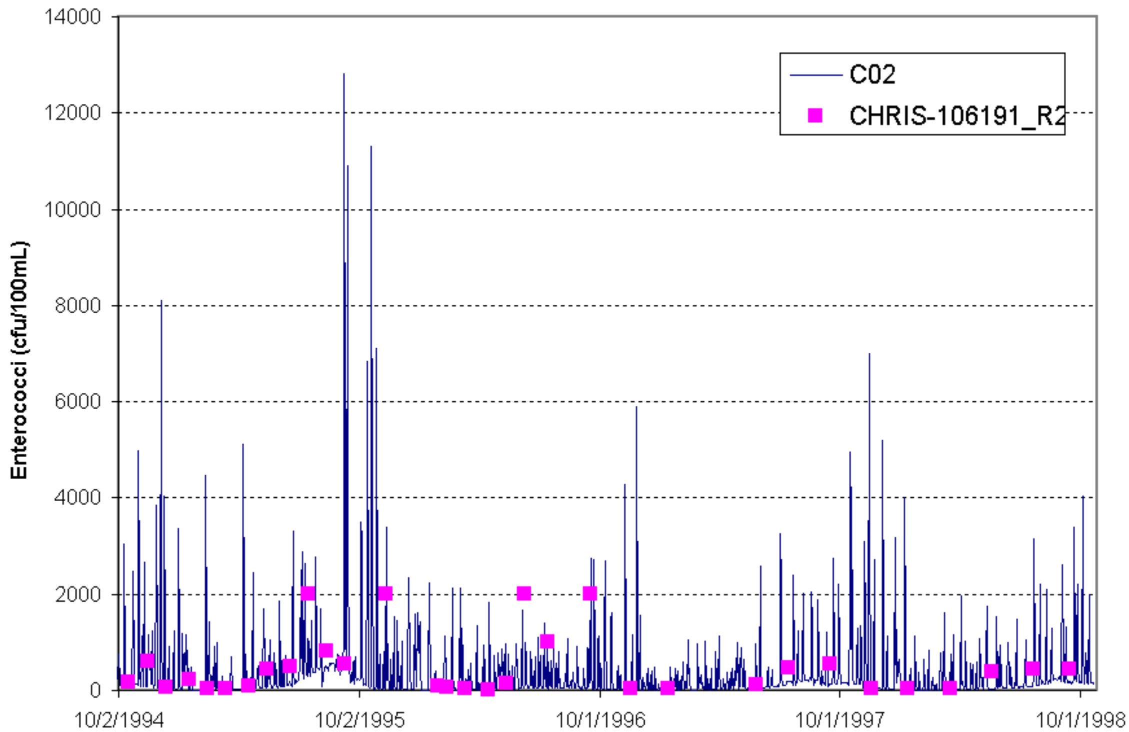
Enterococci Bacteria Simulation

Time-series Calibration Results
(10/1/1994 to 10/29/1998)

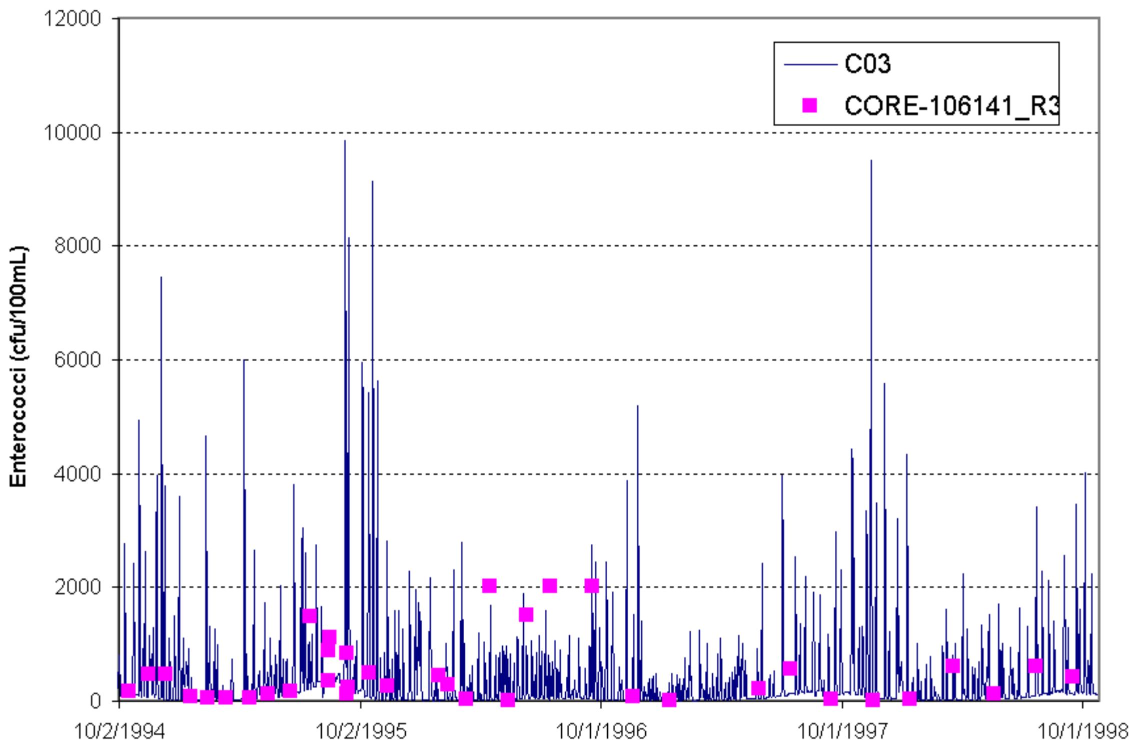
Christina River Watershed

Model results are daily average

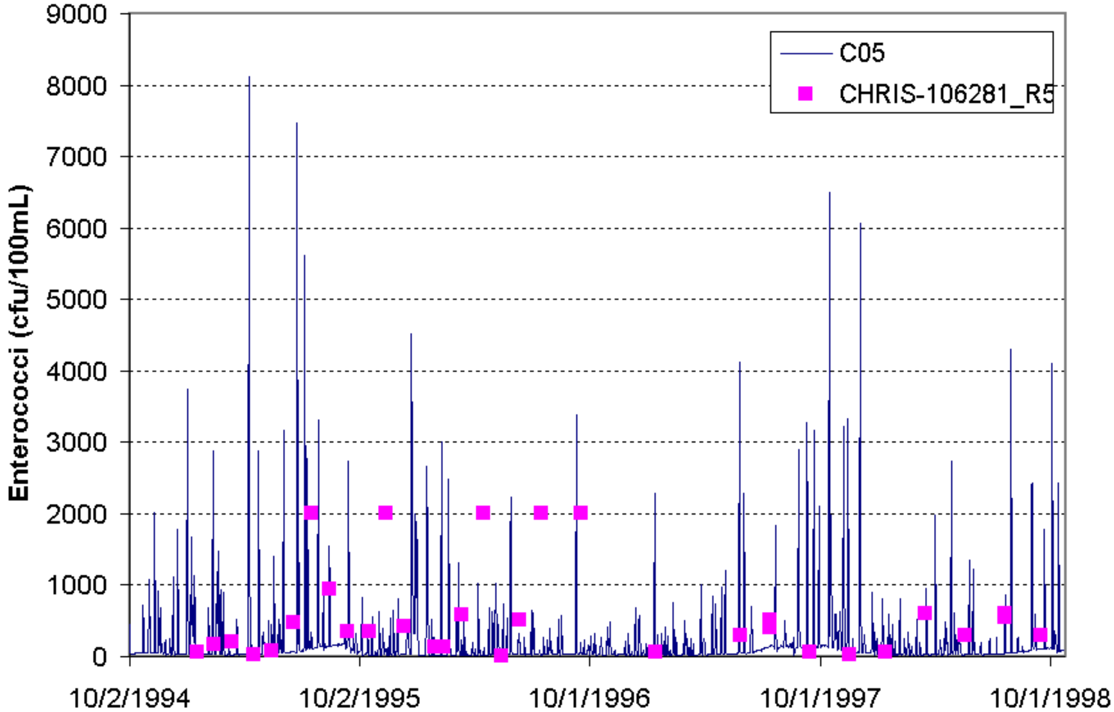
Field observations are grab samples (approximately monthly)



C02
CHRIS-106191_R2
Enterococci (cfu/100mL)
14000
12000
10000
8000
6000
4000
2000
0
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998



C03
CORE-106141_R3
Enterococci (cfu/100mL)
12000
10000
8000
6000
4000
2000
0
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998



9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Enterococci (cfu/100mL)
C05
CHRIS-106281_R5
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998

Appendix E

HSPF Model

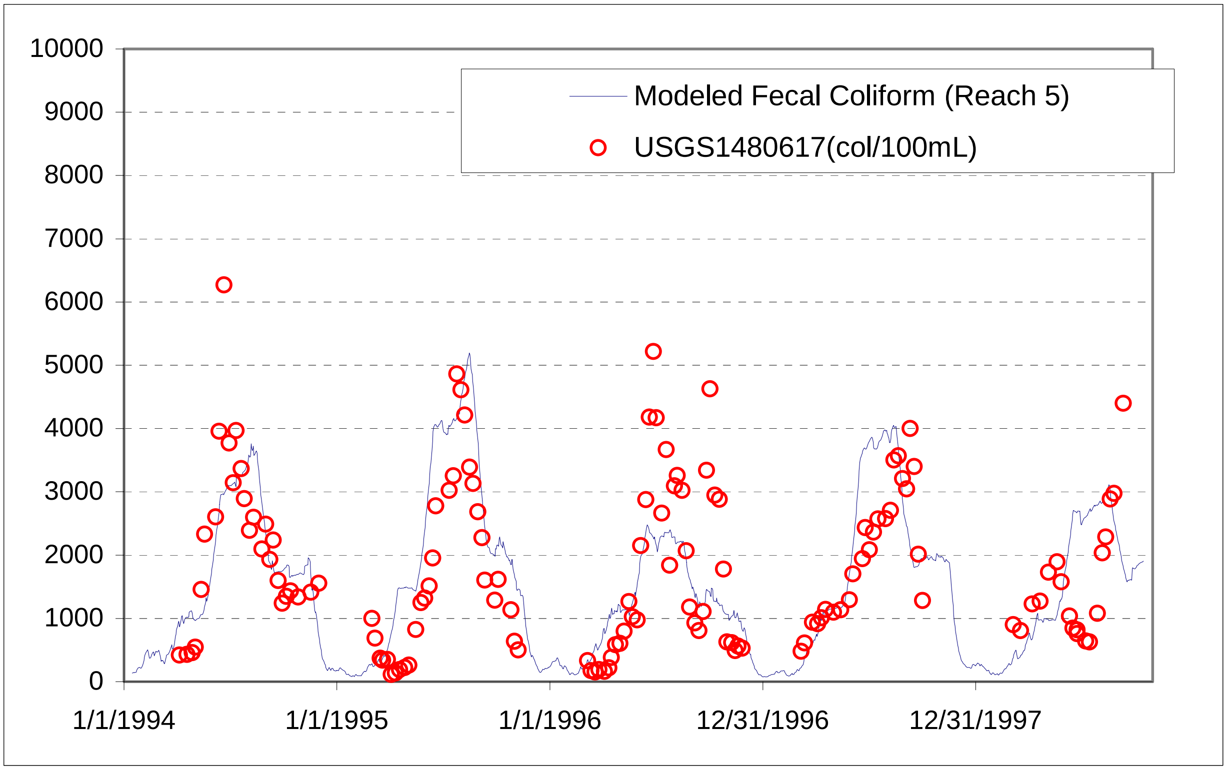
Fecal Coliform Bacteria Simulation

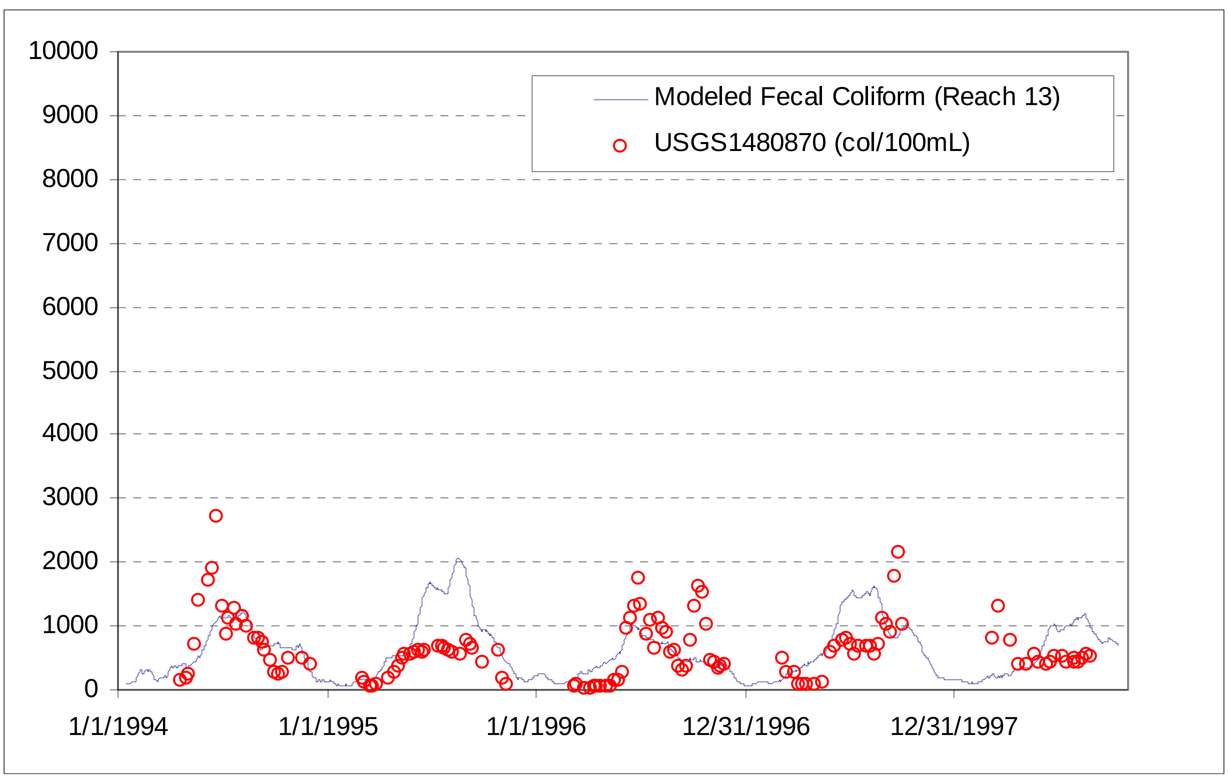
Time-series Calibration Results
(1/1/1994 to 10/29/1998)

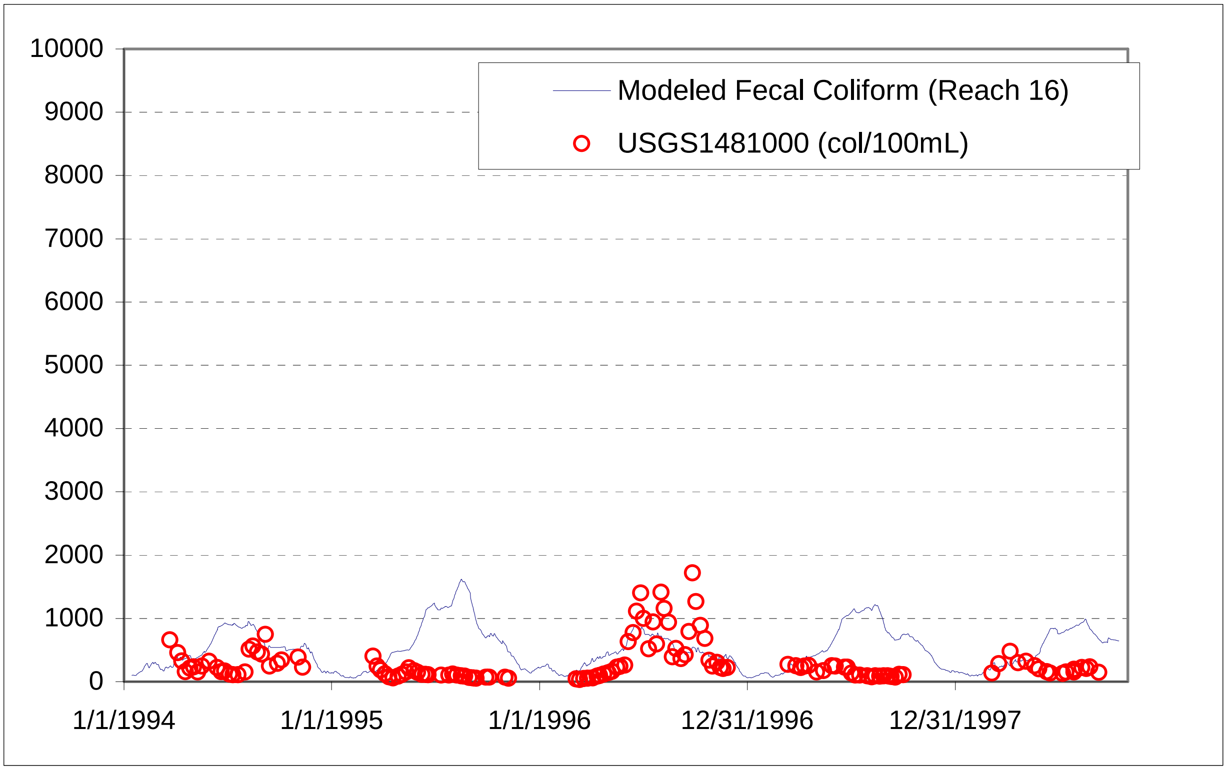
Brandywine Creek Watershed
at
Modena (01480617)
Downingtown (01480870)
Chadds Ford (01481000)

(y-axis units: cfu/100mL)

Model and Data are 30-day geometric mean


10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1/1/1994
1/1/1995
1/1/1996
12/31/1996
12/31/1997
Modeled Fecal Coliform (Reach 5)
USGS1480617(col/100mL)


10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1/1/1994
1/1/1995
1/1/1996
12/31/1996
12/31/1997
Modeled Fecal Coliform (Reach 13)
USGS1480870 (col/100mL)



10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Modeled Fecal Coliform (Reach 16)
USGS1481000 (col/100mL)
1/1/1994
1/1/1995
1/1/1996
12/31/1996
12/31/1997

Appendix F

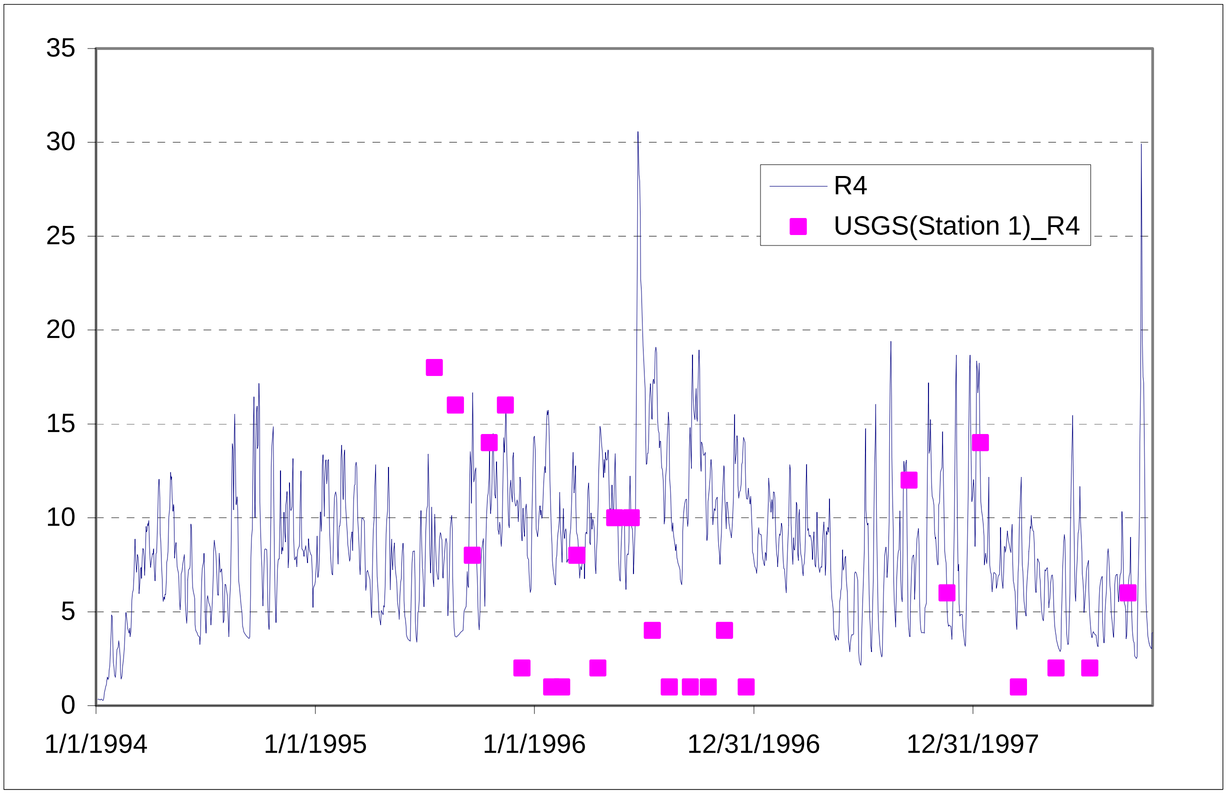
HSPF Model

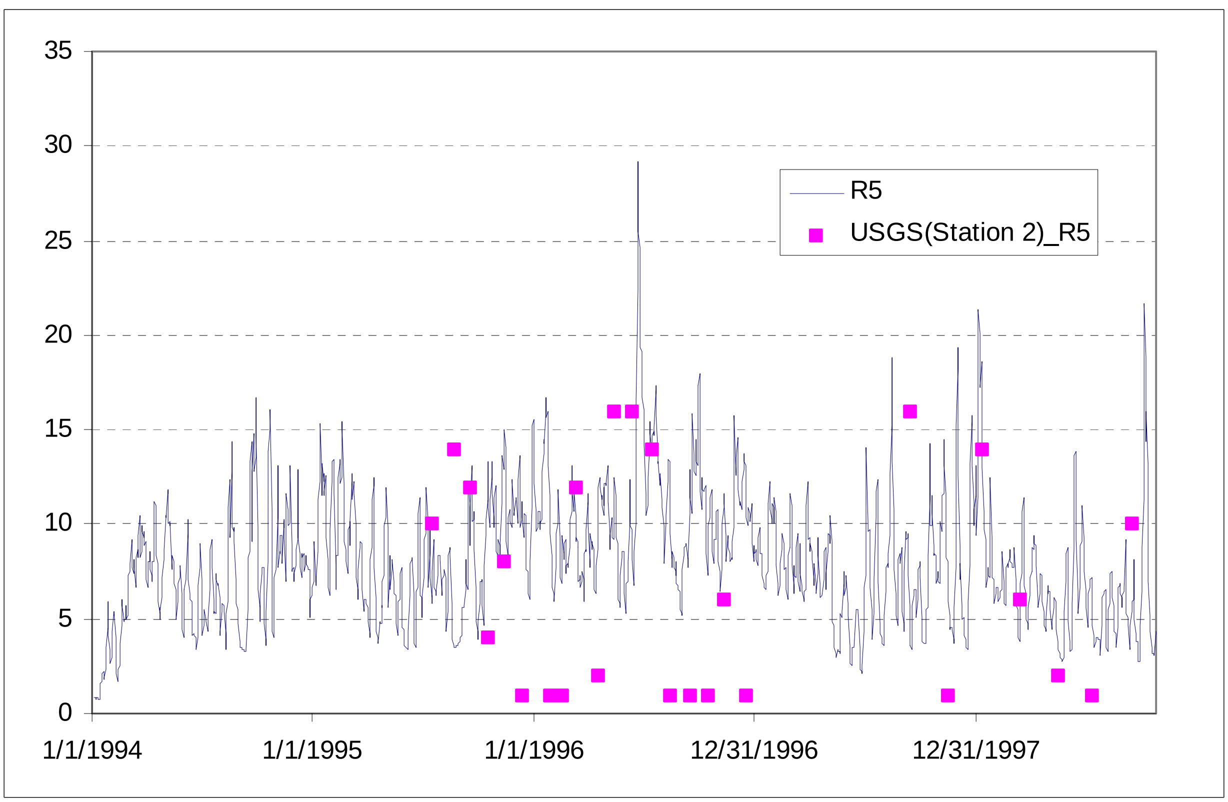
Suspended Sediment Simulation

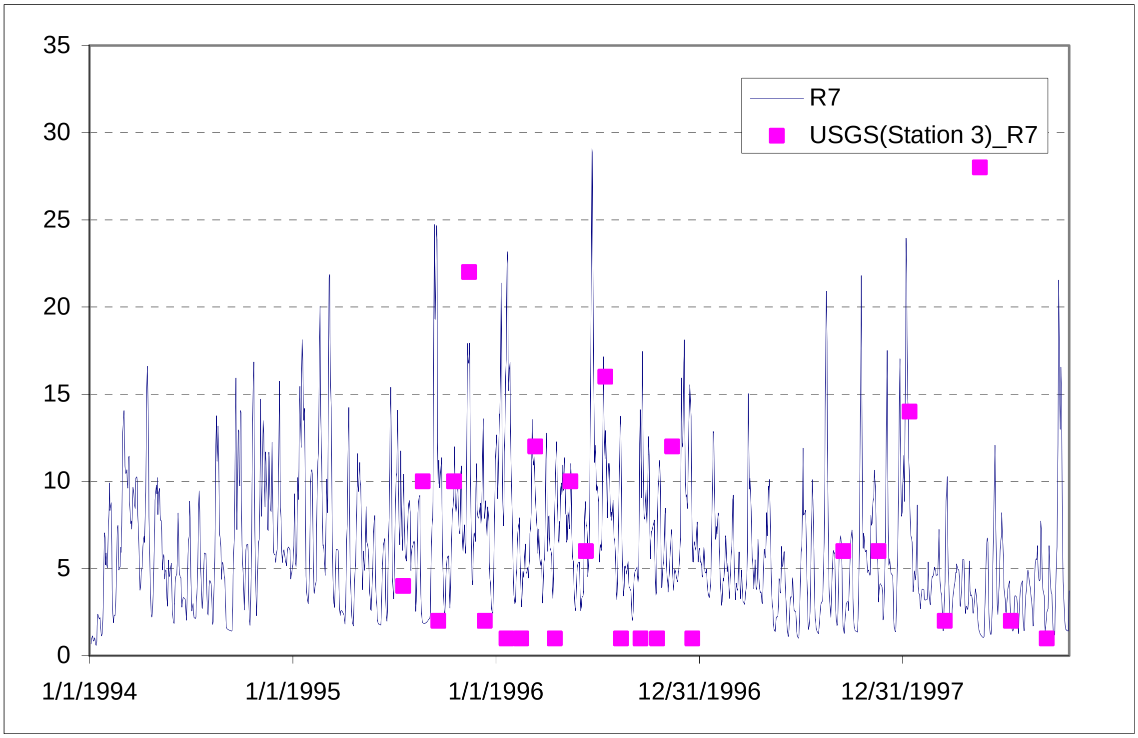
Time-series Calibration Results
(1/1/1994 to 10/29/1998)

Brandywine Creek Watershed

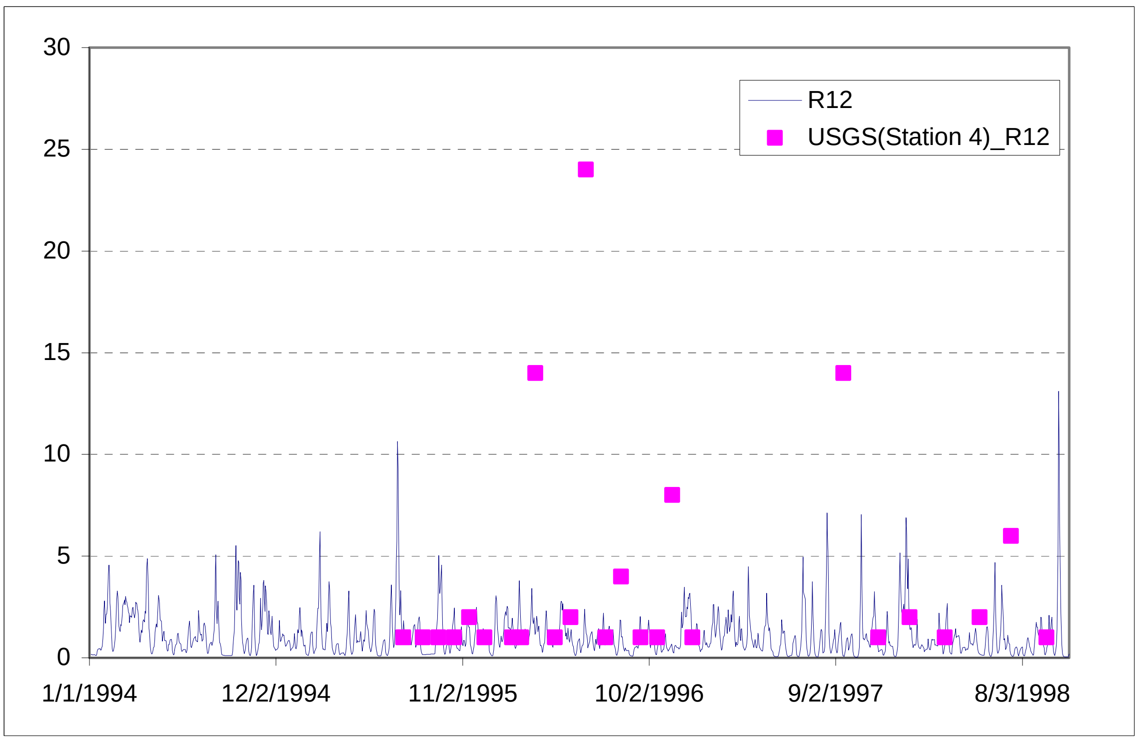
(y-axis units are mg/L)


35
30
25
20
15
10
5
0
1/1/1994
1/1/1995
1/1/1996
12/31/1996
12/31/1997
R4
USGS(Station 1)_R4

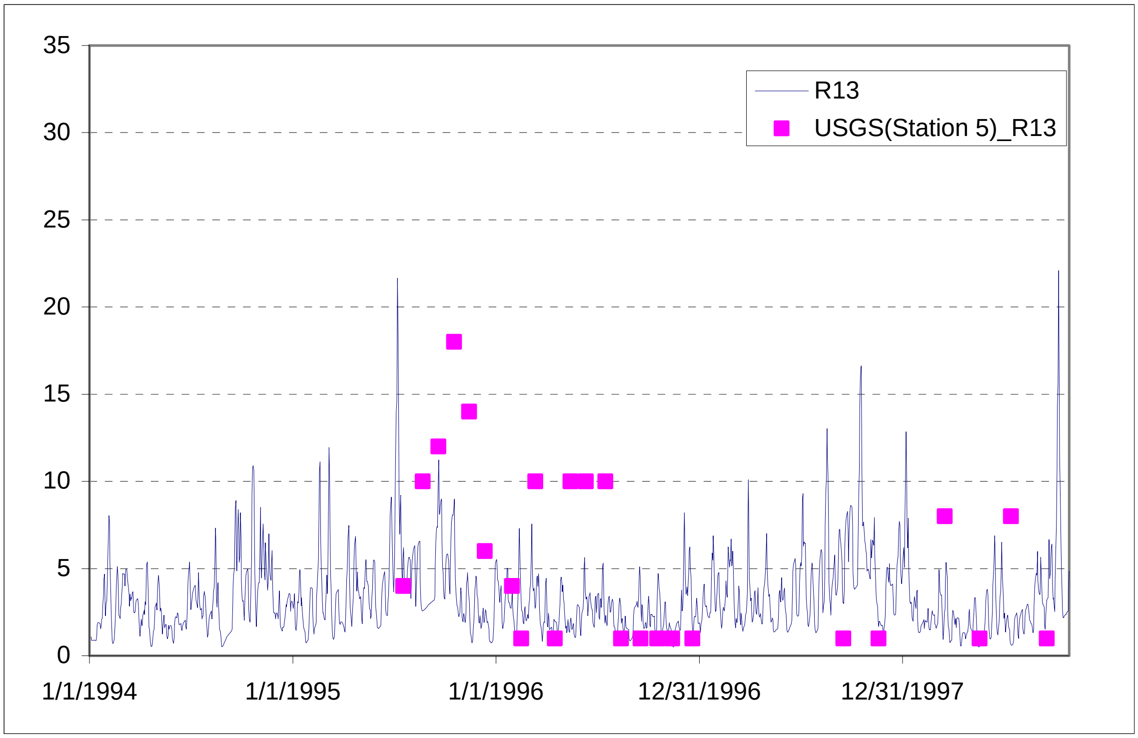

35
30
25
20
15
10
5
0
1/1/1994
1/1/1995
1/1/1996
12/31/1996
12/31/1997
R5
USGS(Station 2)_R5



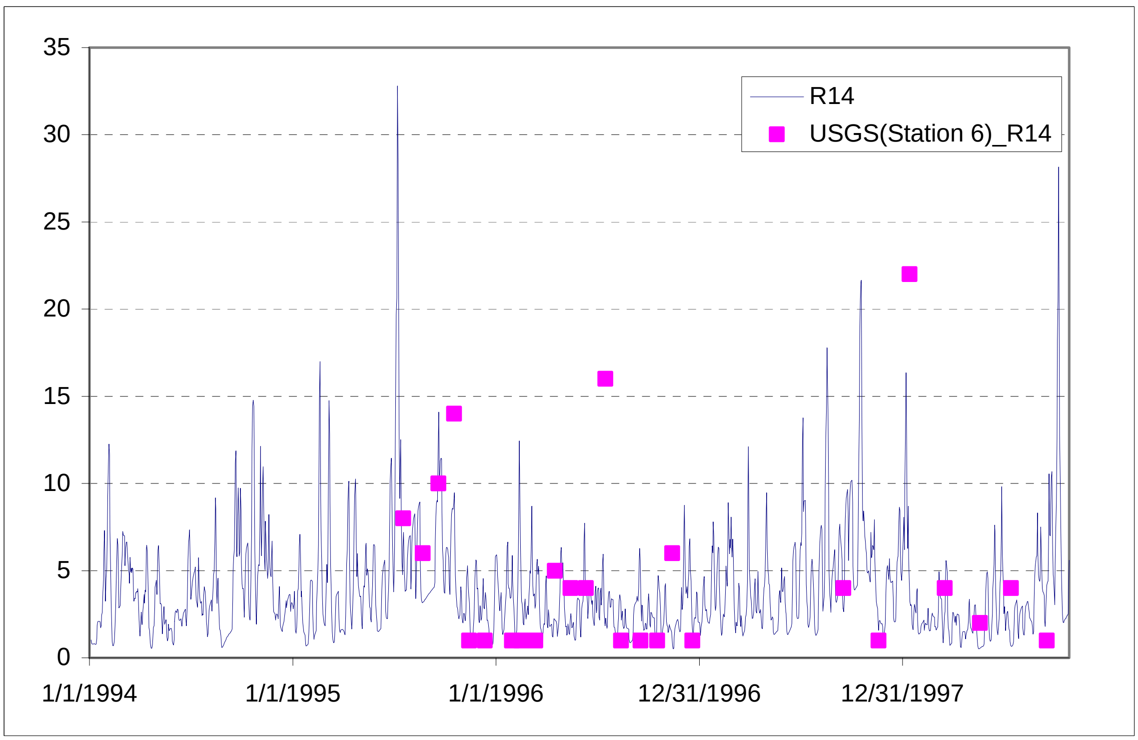
R7
USGS(Station 3)_R7
0
5
10
15
20
25
30
35
1/1/1994
1/1/1995
1/1/1996
12/31/1996
12/31/1997



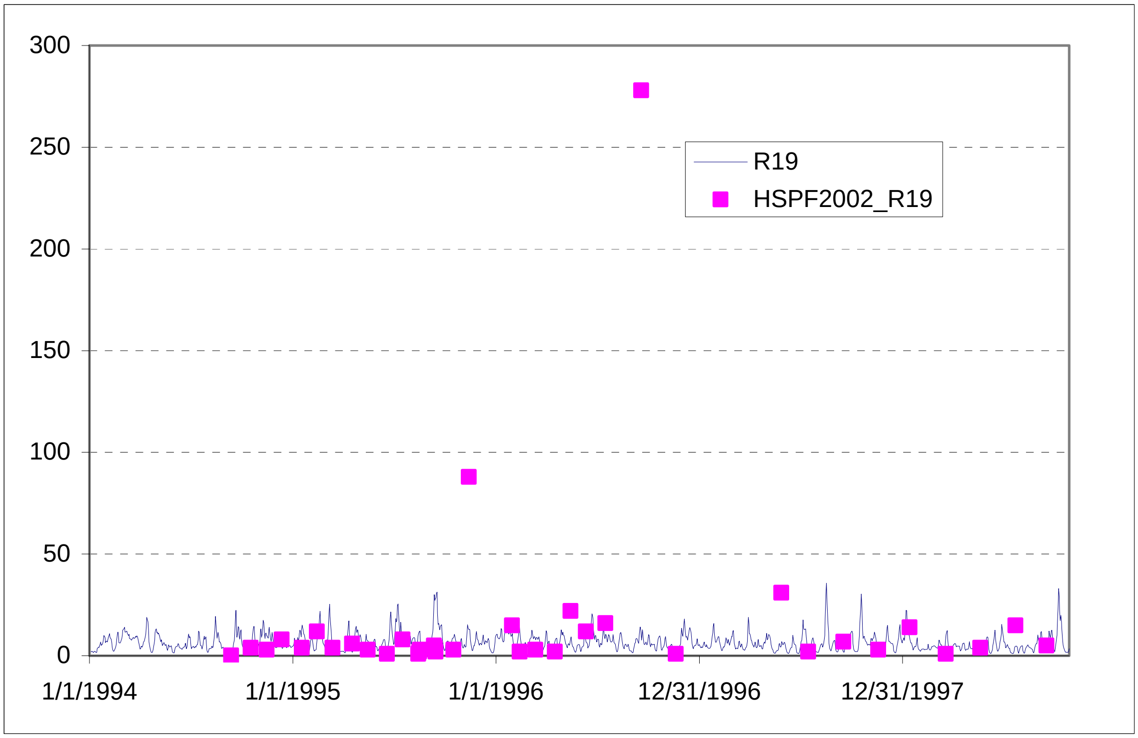
R12
USGS(Station 4)_R12
0
5
10
15
20
25
30
1/1/1994
12/2/1994
11/2/1995
10/2/1996
9/2/1997
8/3/1998



35
30
25
20
15
10
5
0
1/1/1994
1/1/1995
1/1/1996
12/31/1996
12/31/1997
R13
USGS(Station 5)_R13



35
30
25
20
15
10
5
0
1/1/1994
1/1/1995
1/1/1996
12/31/1996
12/31/1997
R14
USGS(Station 6)_R14



300
250
200
150
100
50
0
1/1/1994
1/1/1995
1/1/1996
12/31/1996
12/31/1997
R19
HSPF2002_R19

Appendix G

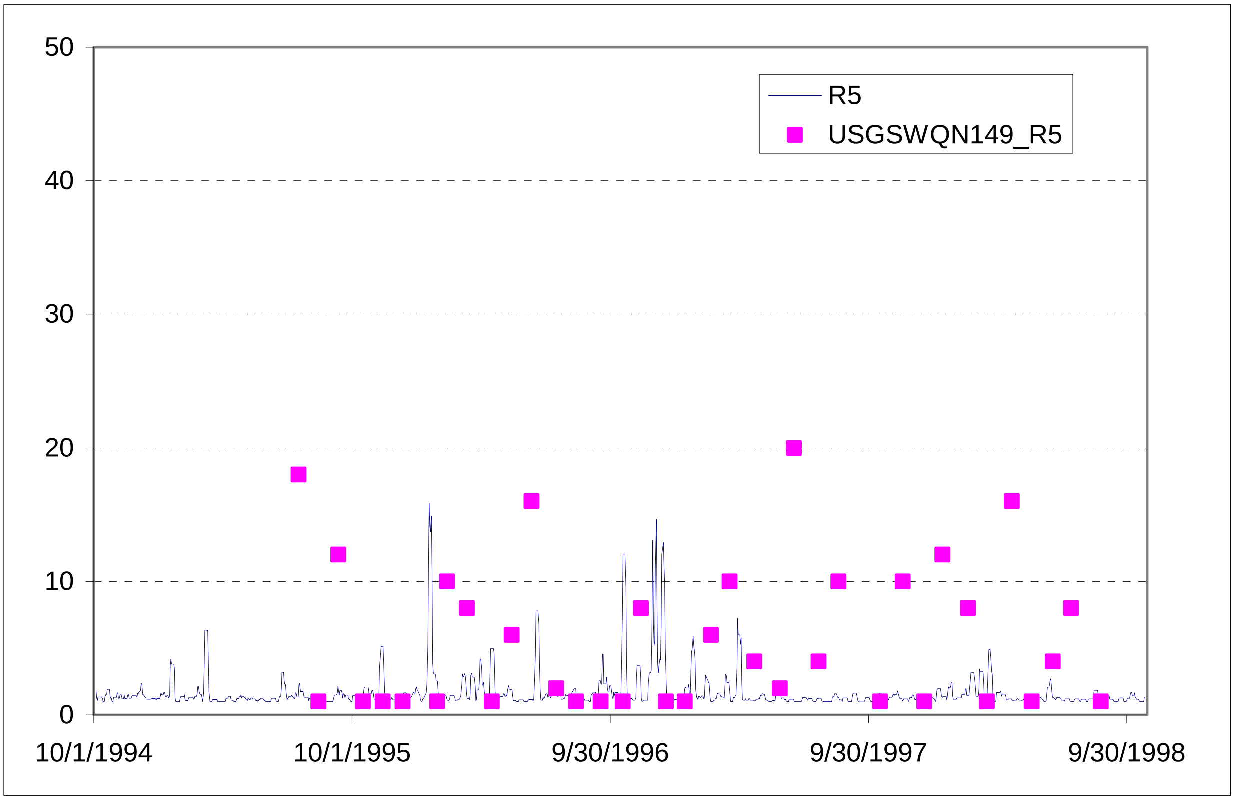
HSPF Model

Suspended Sediment Simulation

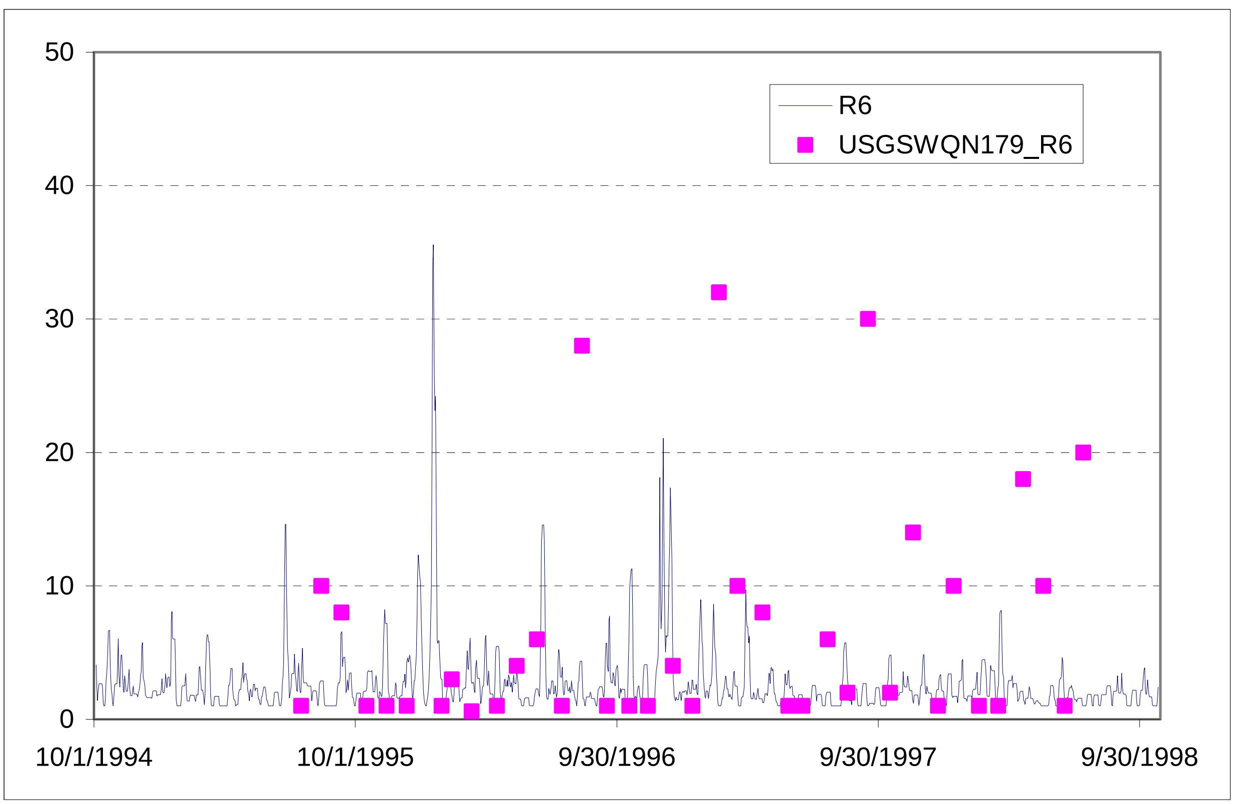
Time-series Calibration Results
(10/1/1994 to 10/29/1998)

White Clay Creek Watershed

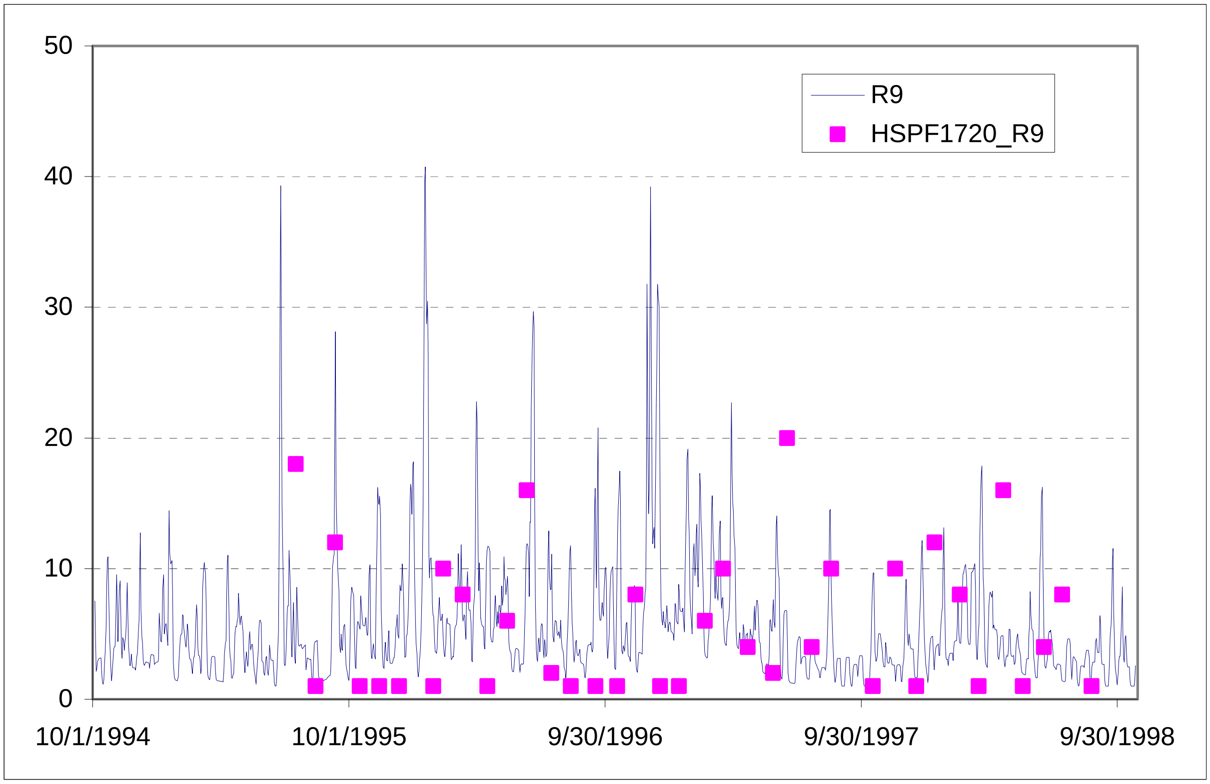
(y-axis units are mg/L)



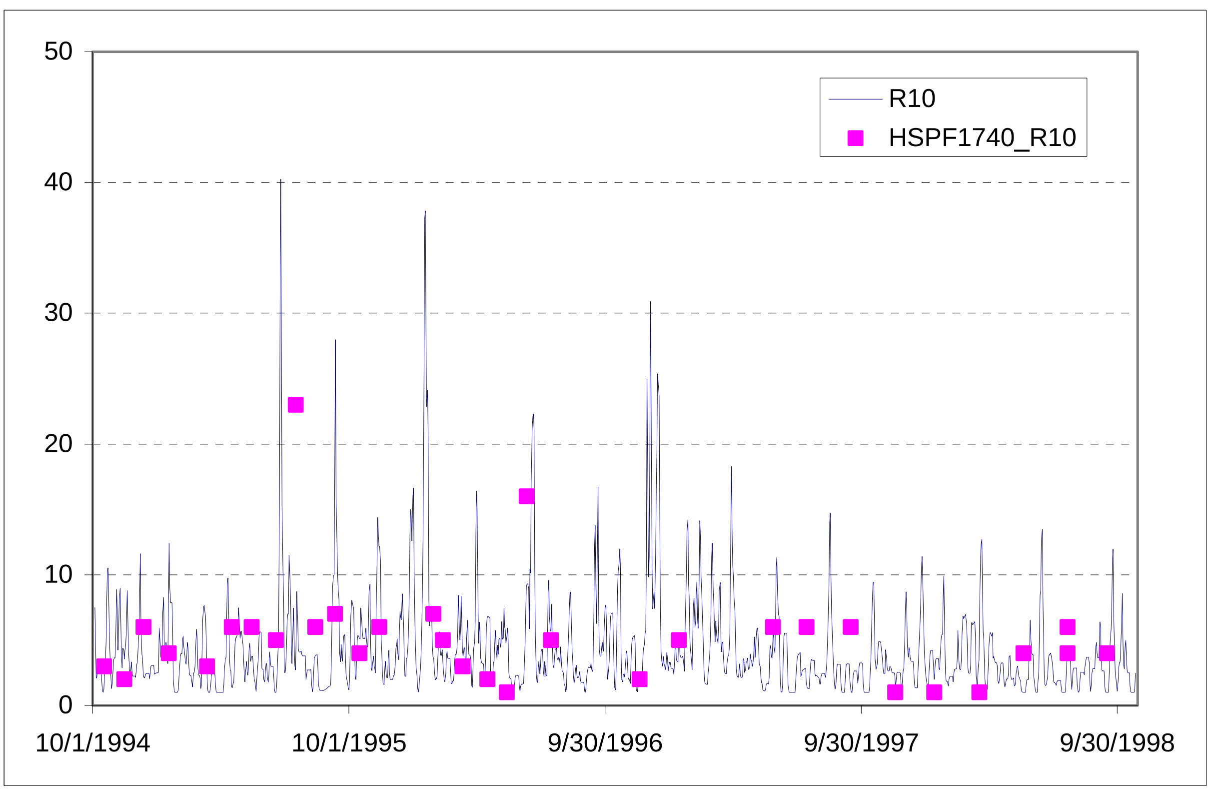
50
40
30
20
10
0
10/1/1994
10/1/1995
9/30/1996
9/30/1997
9/30/1998
R5
USGSWQN149_R5



50
40
30
20
10
0
10/1/1994
10/1/1995
9/30/1996
9/30/1997
9/30/1998
R6
USGSWQN179_R6



50
40
30
20
10
0
10/1/1994
10/1/1995
9/30/1996
9/30/1997
9/30/1998
R9
HSPF1720_R9



50
40
30
20
10
0
10/1/1994
10/1/1995
9/30/1996
9/30/1997
9/30/1998
R10
HSPF1740_R10

Appendix H

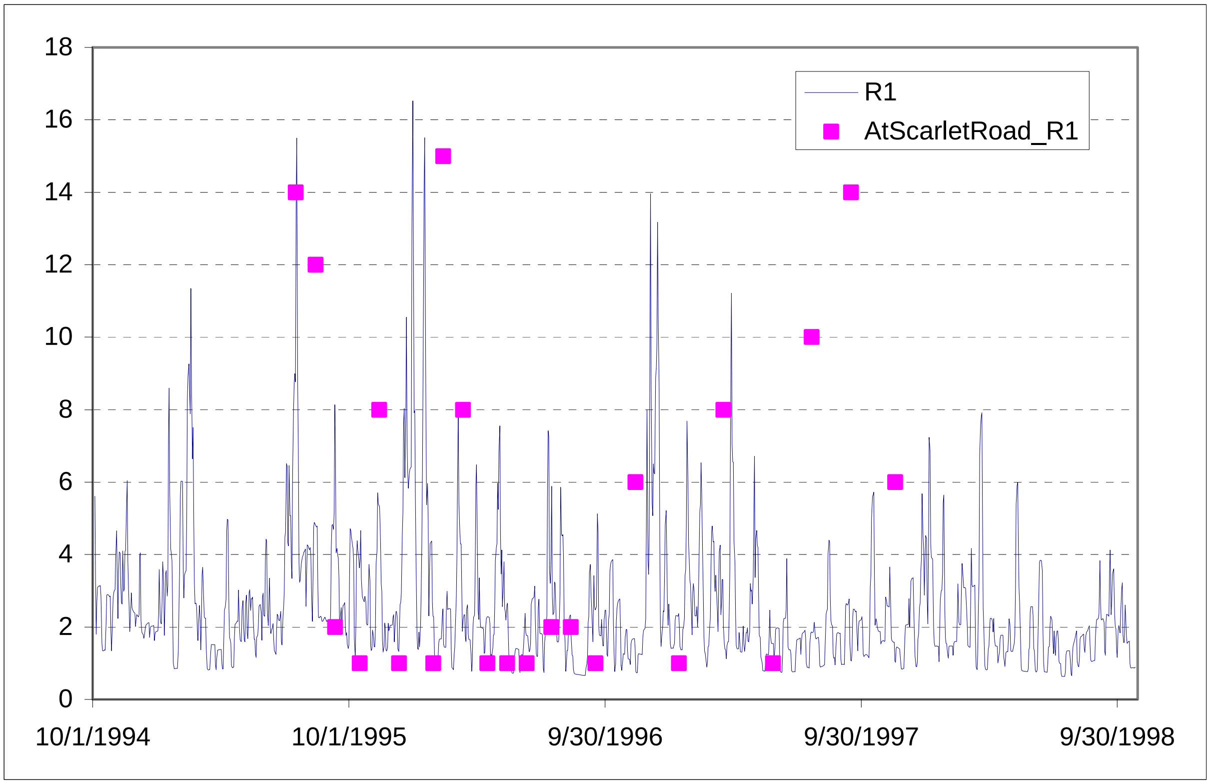
HSPF Model

Suspended Sediment Simulation

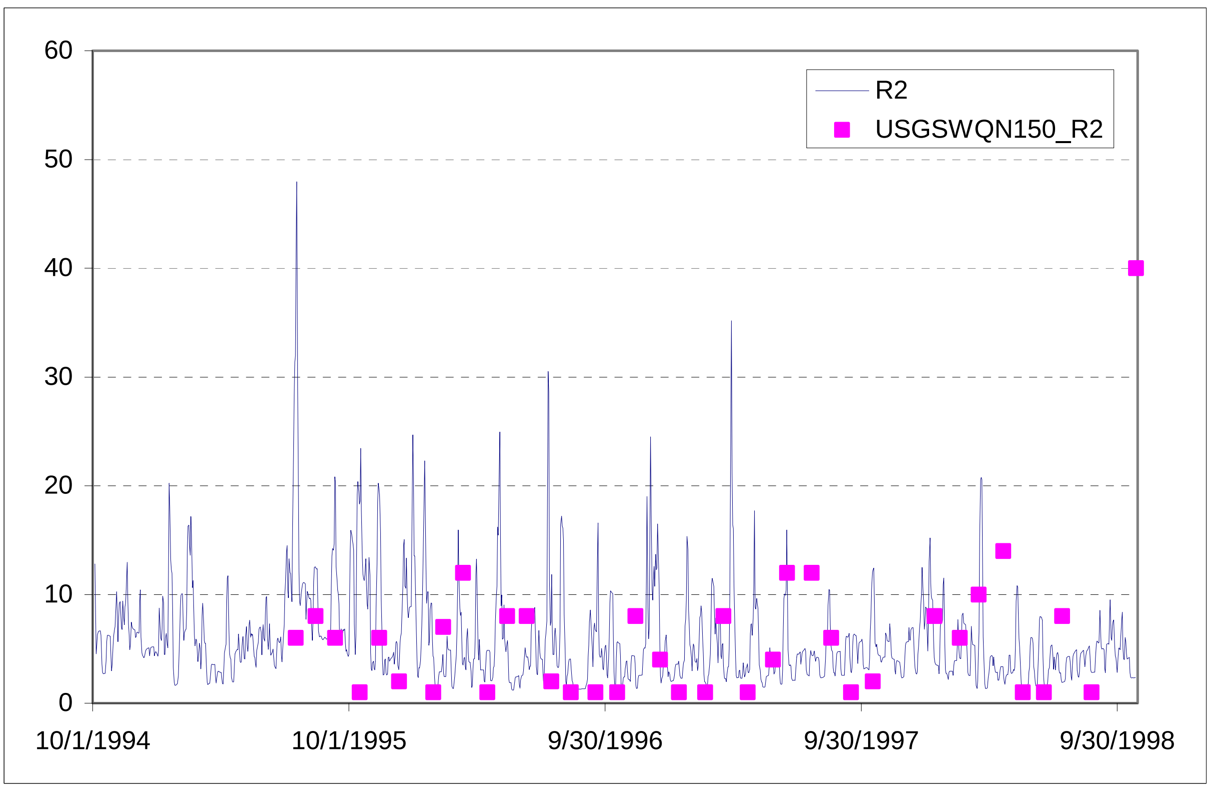
Time-series Calibration Results
(10/1/1994 to 10/29/1998)

Red Clay Creek Watershed

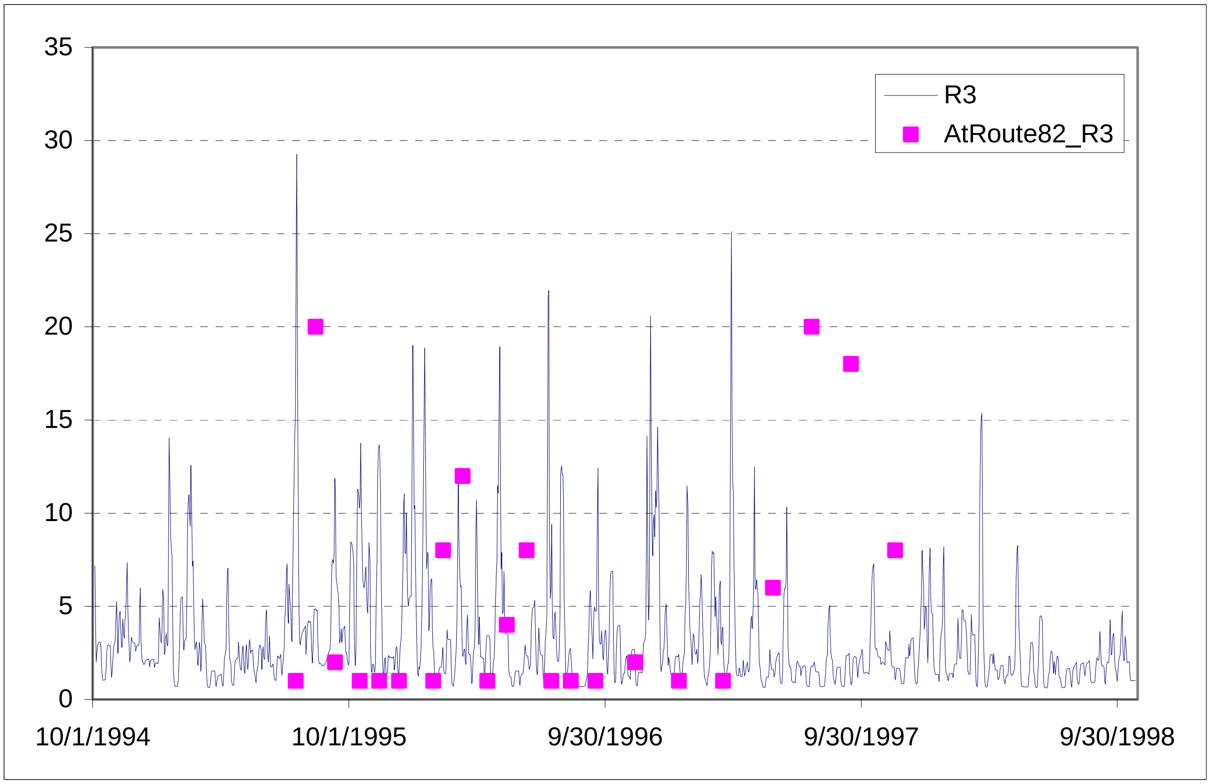
(y-axis units are mg/L)

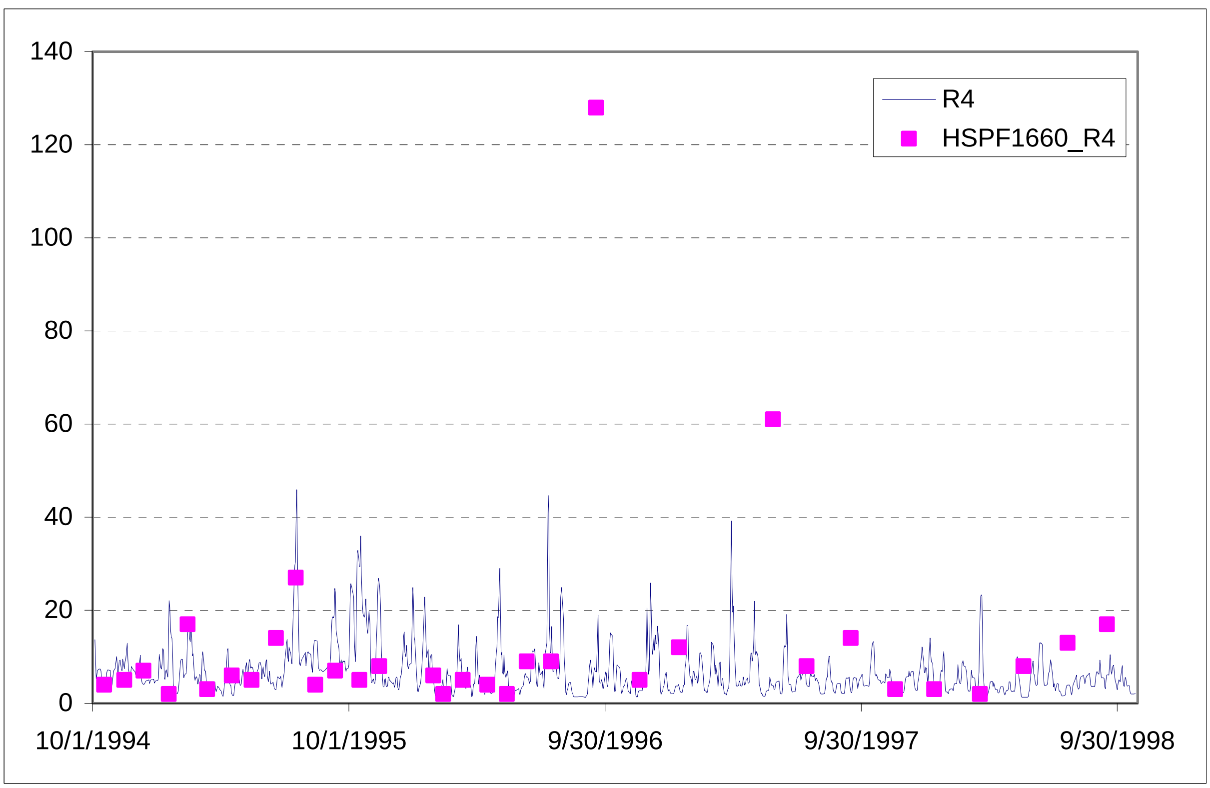


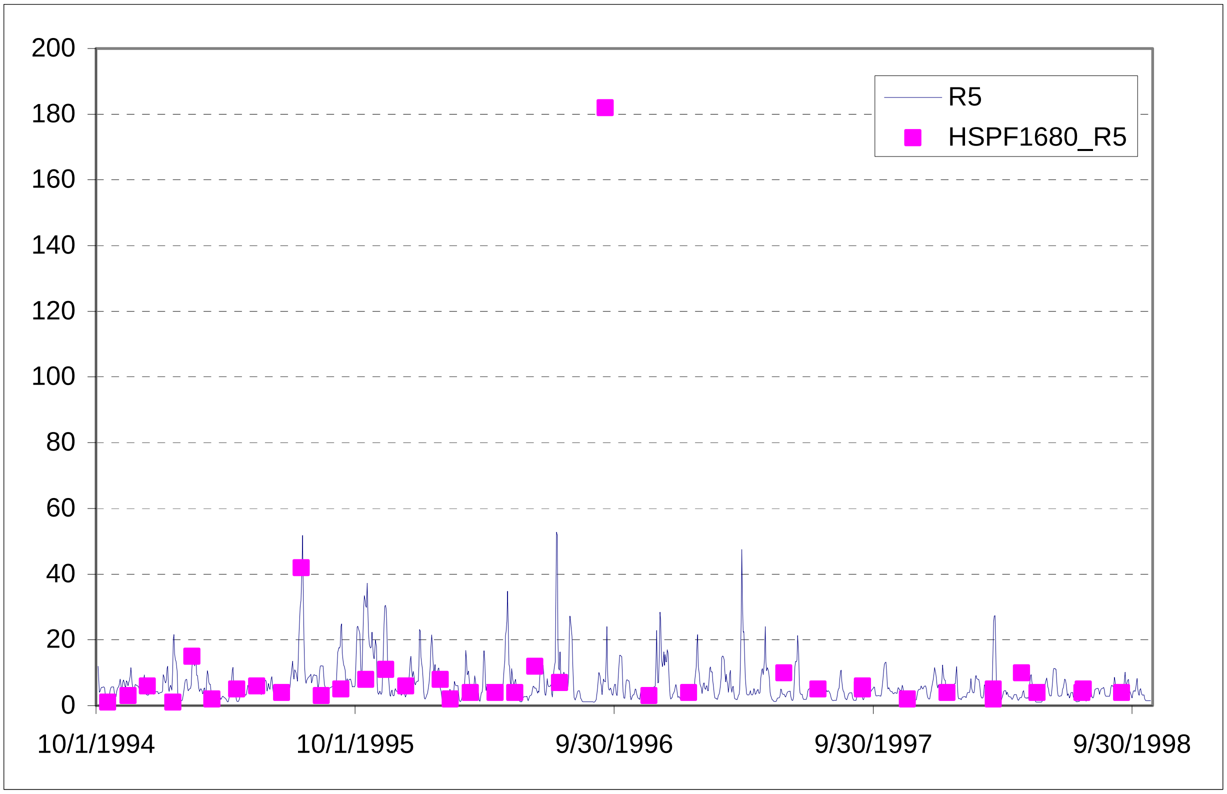
18
16
14
12
10
8
6
4
2
0
R1
AtScarletRoad_R1
10/1/1994
10/1/1995
9/30/1996
9/30/1997
9/30/1998



60
50
40
30
20
10
0
R2
USGSWQN150_R2
10/1/1994
10/1/1995
9/30/1996
9/30/1997
9/30/1998


35
30
25
20
15
10
5
0
10/1/1994
10/1/1995
9/30/1996
9/30/1997
9/30/1998
R3
AtRoute82_R3


140
120
100
80
60
40
20
0
10/1/1994
10/1/1995
9/30/1996
9/30/1997
9/30/1998
R4
HSPF1660_R4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180
160
140
120
100
80
60
40
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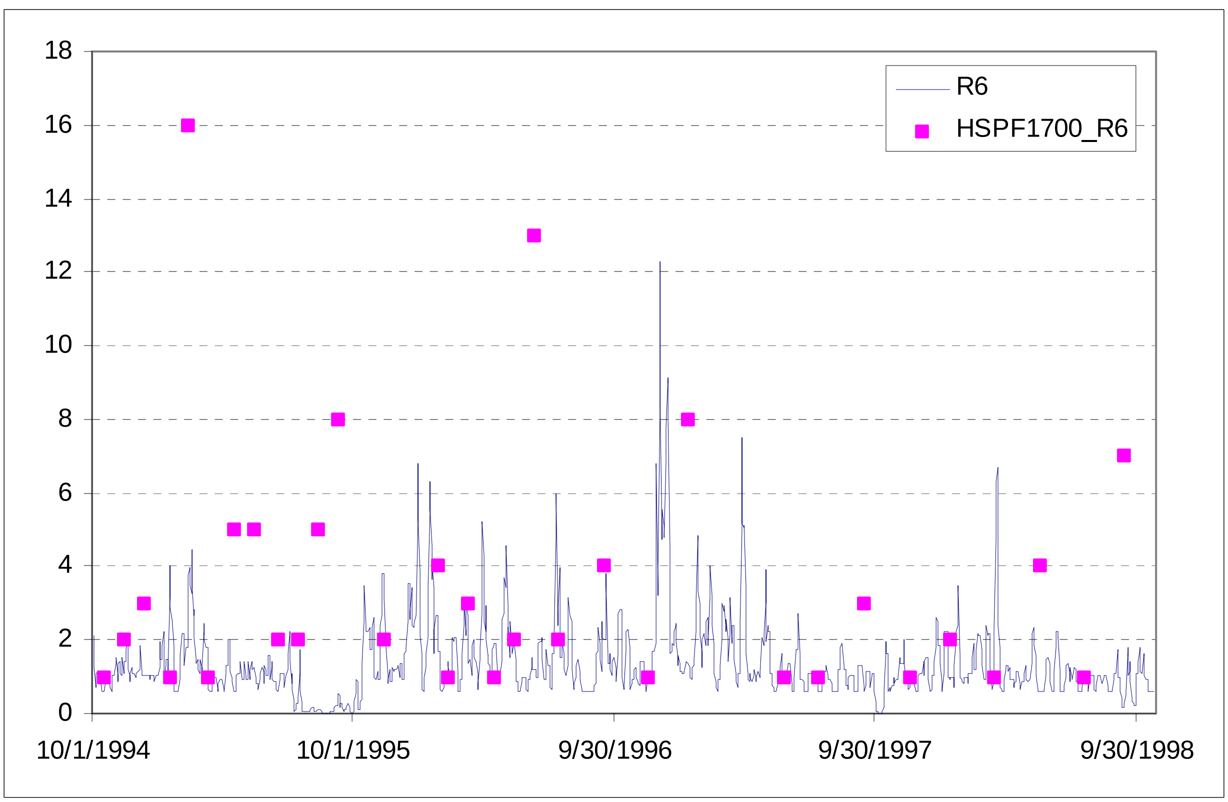
10/1/1994
10/1/1995
9/30/1996
9/30/1997
9/30/1998
R5
HSPF1680_R5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16
14
12
10
8
6
4
2
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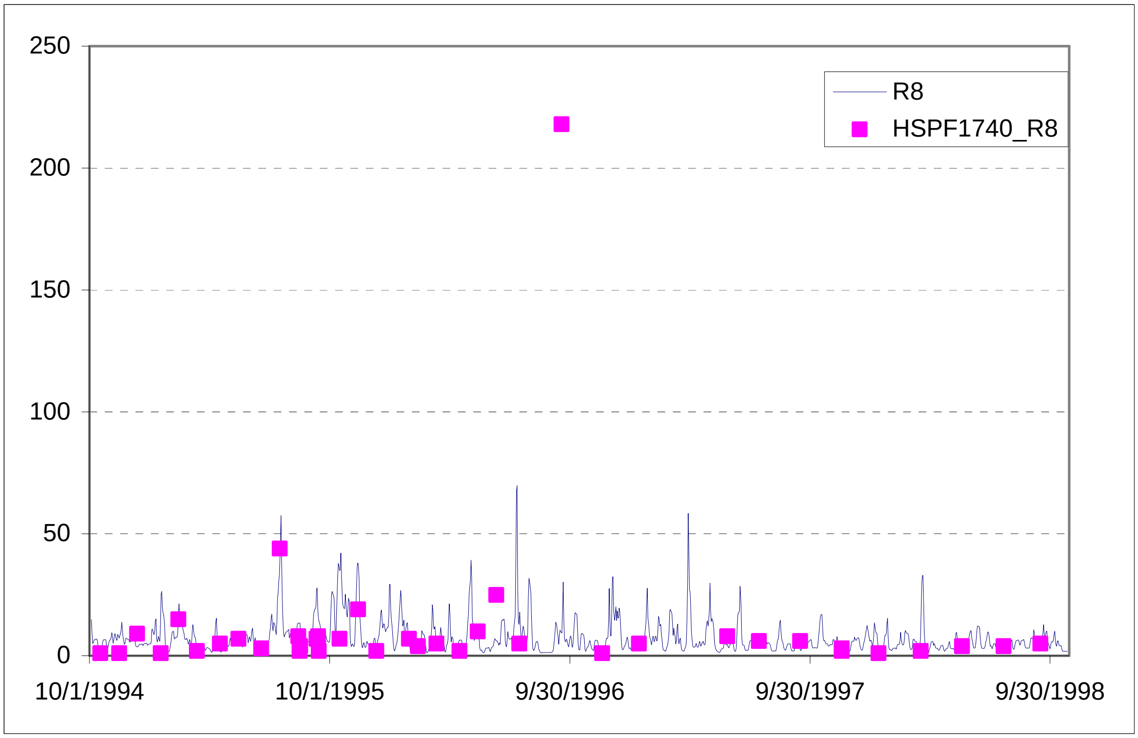
10/1/1995
9/30/1996
9/30/1997
9/30/1998
R6
HSPF1700_R6



250
200
150
100
50
0
10/1/1994
10/1/1995
9/30/1996
9/30/1997
9/30/1998
R8
HSPF1740_R8

Appendix I

EFDC Model

Enterococci Bacteria Simulation

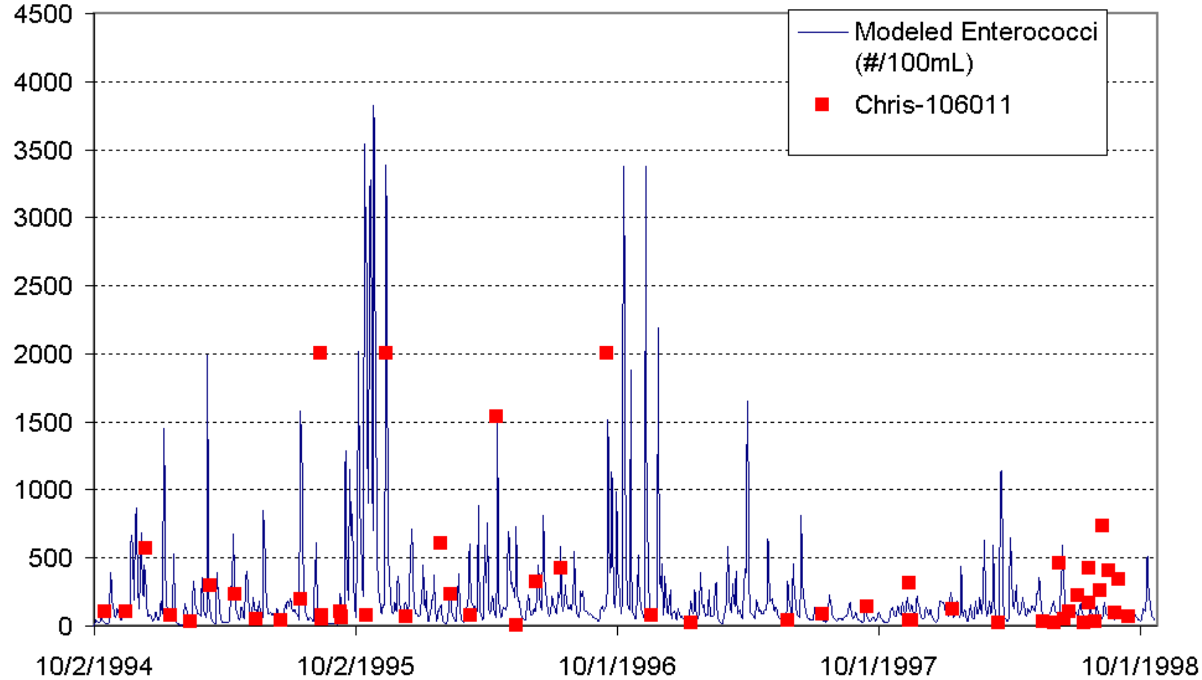
Time-series Calibration Results
(10/1/1994 to 10/29/1998)

Tidal Christina River
Tidal Brandywine Creek

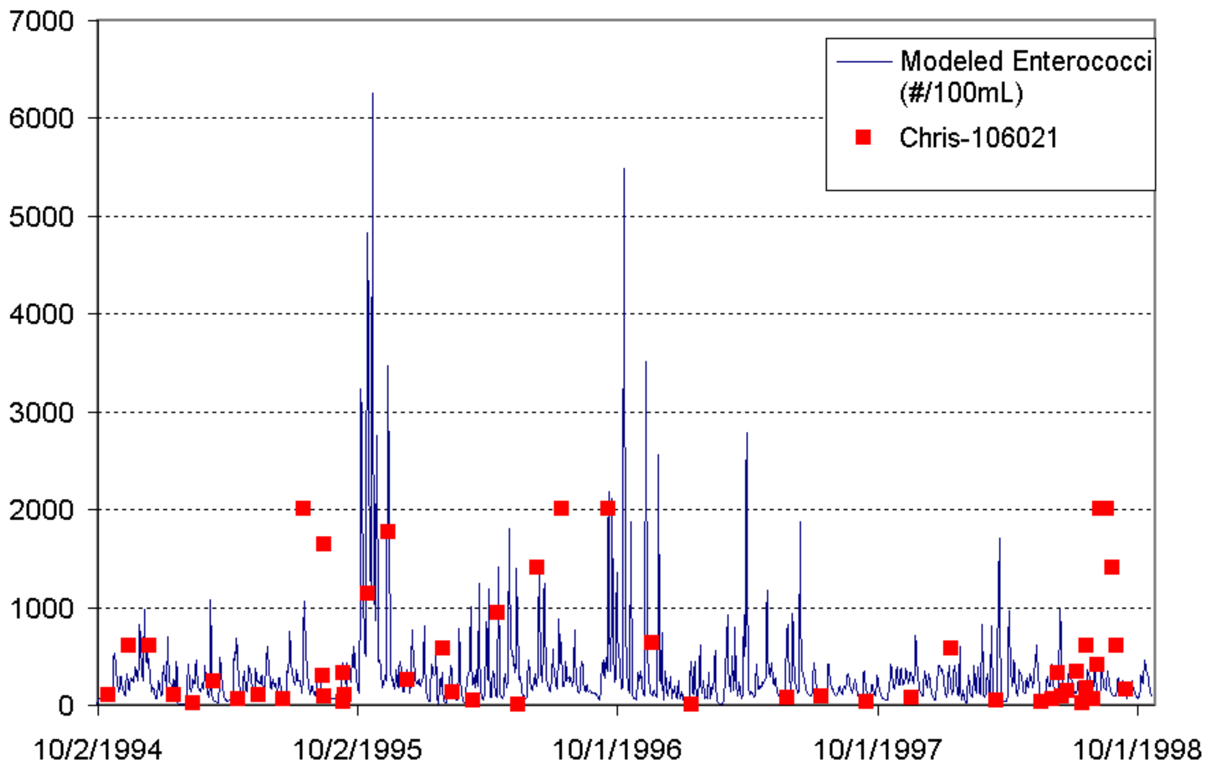
(y-axis units are cfu/100 mL)

Model results are daily average.

Field observations are grab samples (approximately monthly).



4500
4000
3500
3000
2500
2000
1500
1000
500
0
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998
Modeled Enterococci (#/100mL)
Chris-106011



7000
6000
5000
4000
3000
2000
1000
0
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998
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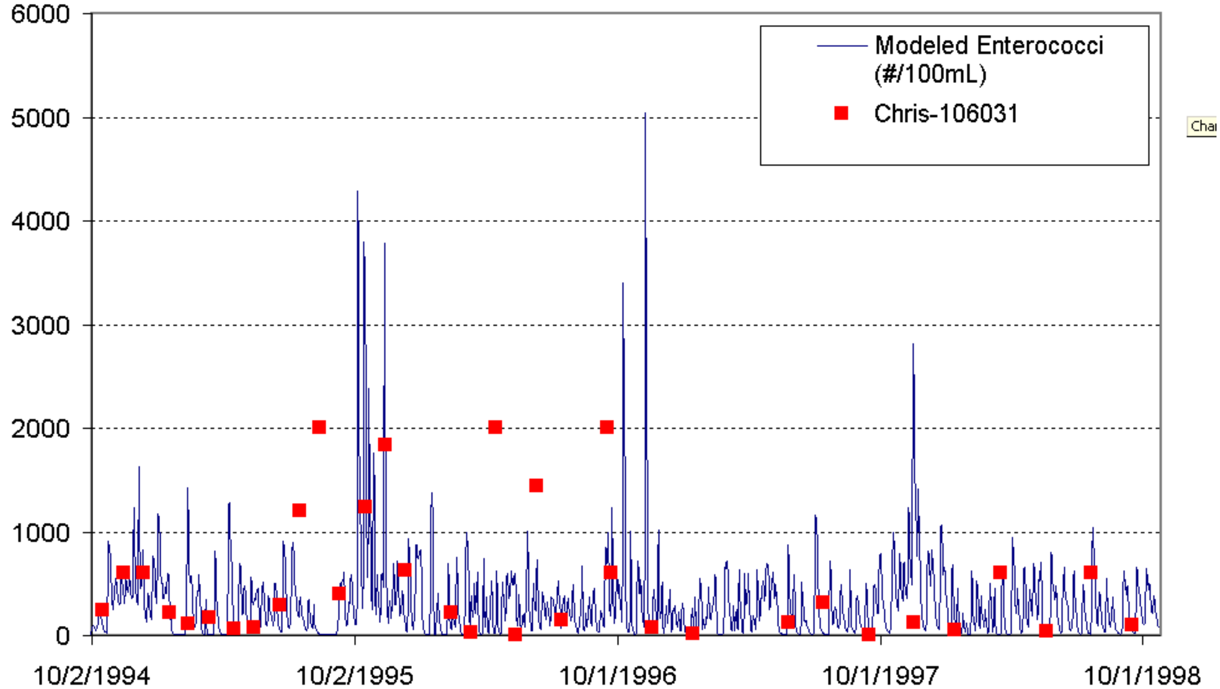
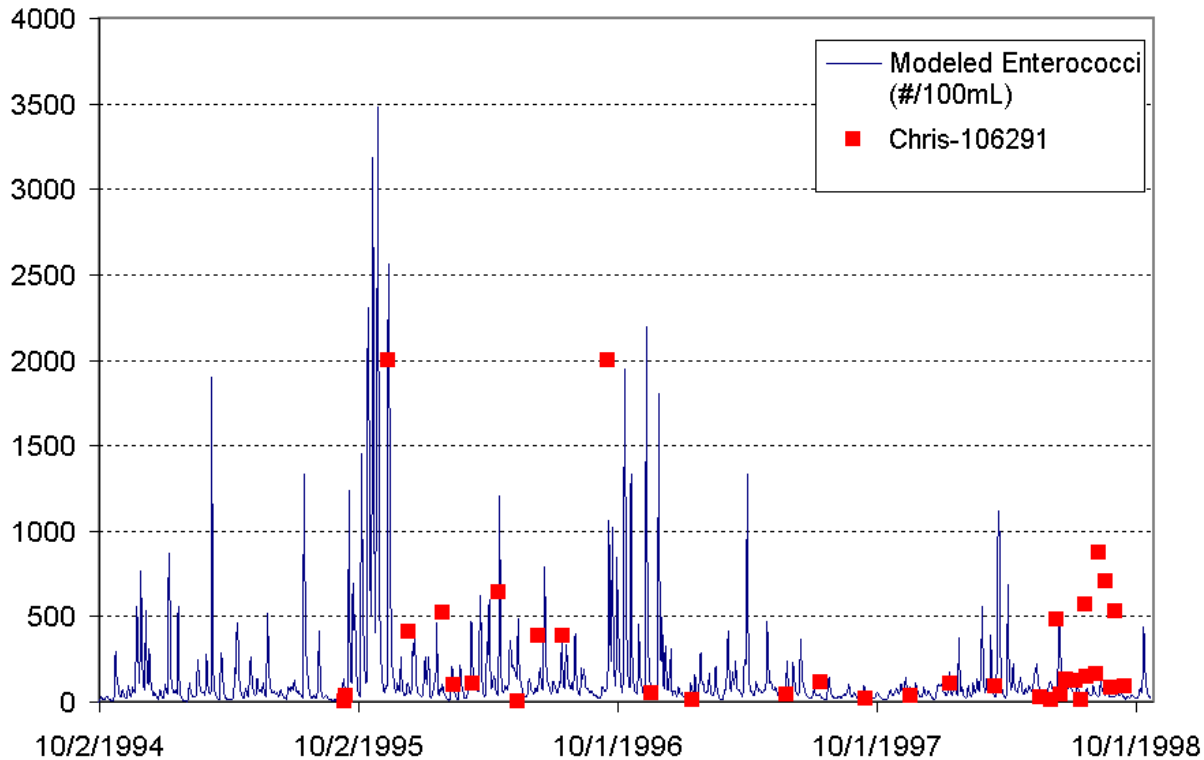
Chris-106021



6000
5000
4000
3000
2000
1000
0
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998
Modeled Enterococci (#/100mL)
Chris-106031



4000
3500
3000
2500
2000
1500
1000
500
0
10/2/1994
10/2/1995
10/1/1996
10/1/1997
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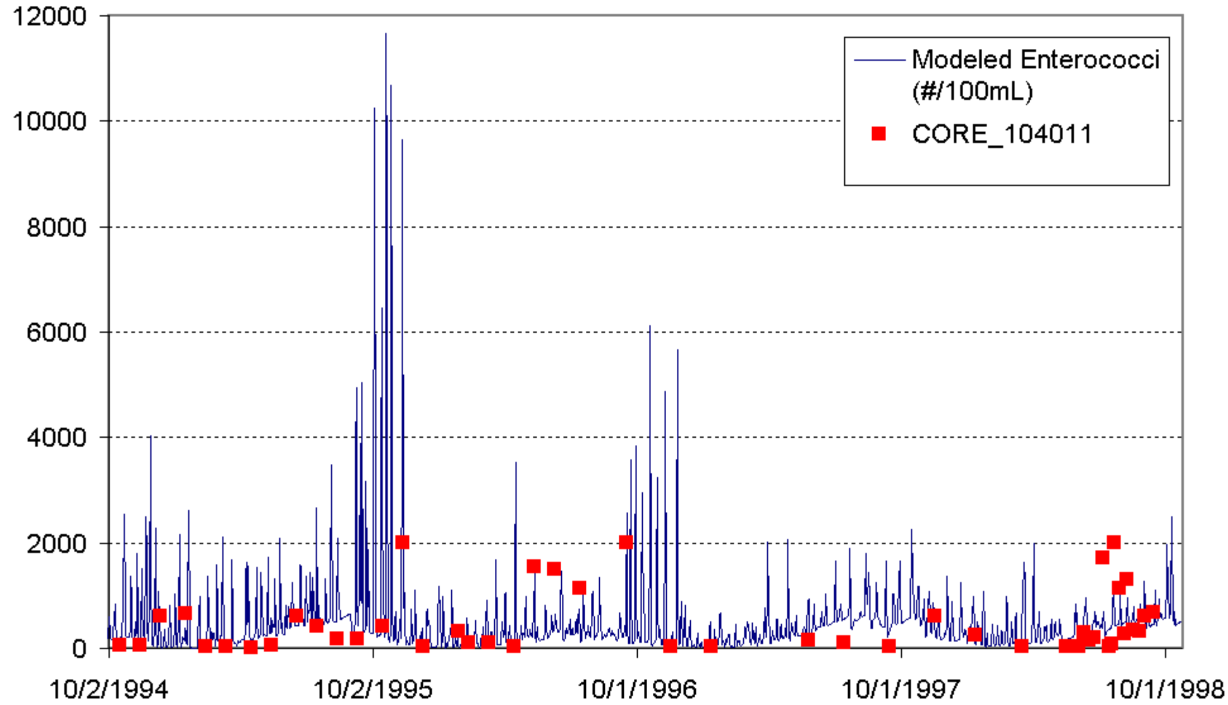
Chris-106291



12000
10000
8000
6000
4000
2000
0
10/2/1994
10/2/1995
10/1/1996
10/1/1997
10/1/1998
Modeled Enterococci (#/100mL)
CORE_104011

Appendix J

Time-series Graphs of Enterococci Baseline and TMDL Allocations

(shown as a moving 30-day geometric mean)

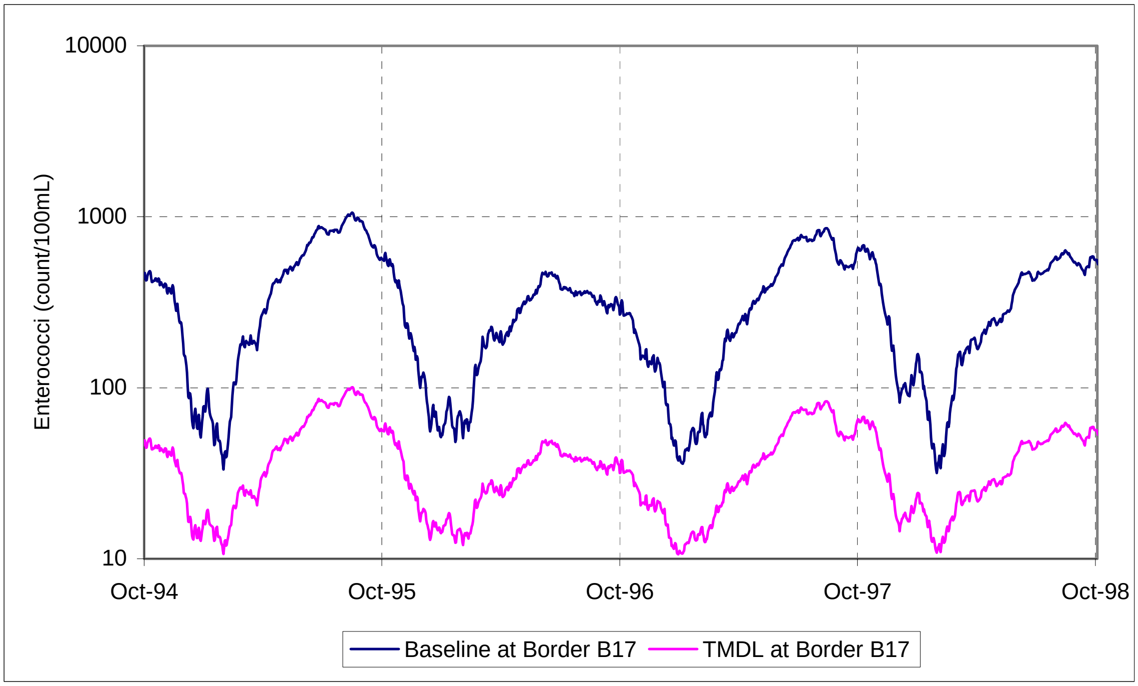


Figure 1. Baseline and TMDL allocation, Brandywine Creek at PA-DE border.

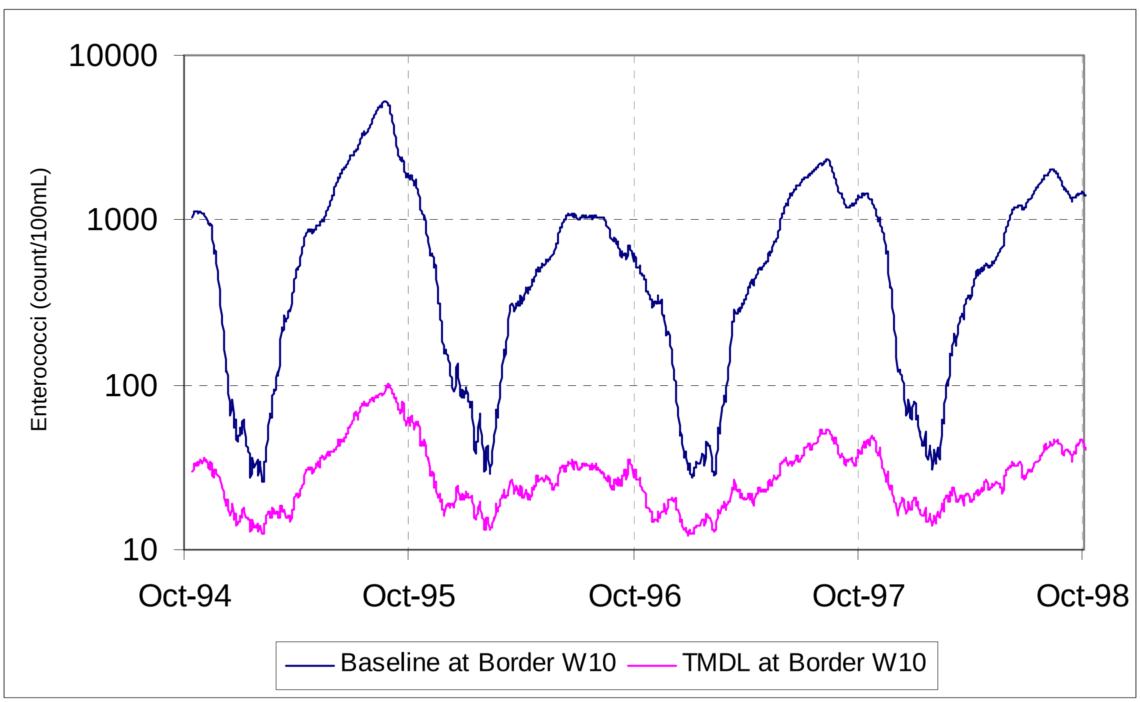


Figure 2. Baseline and TMDL allocation, White Clay Creek at PA-DE border.

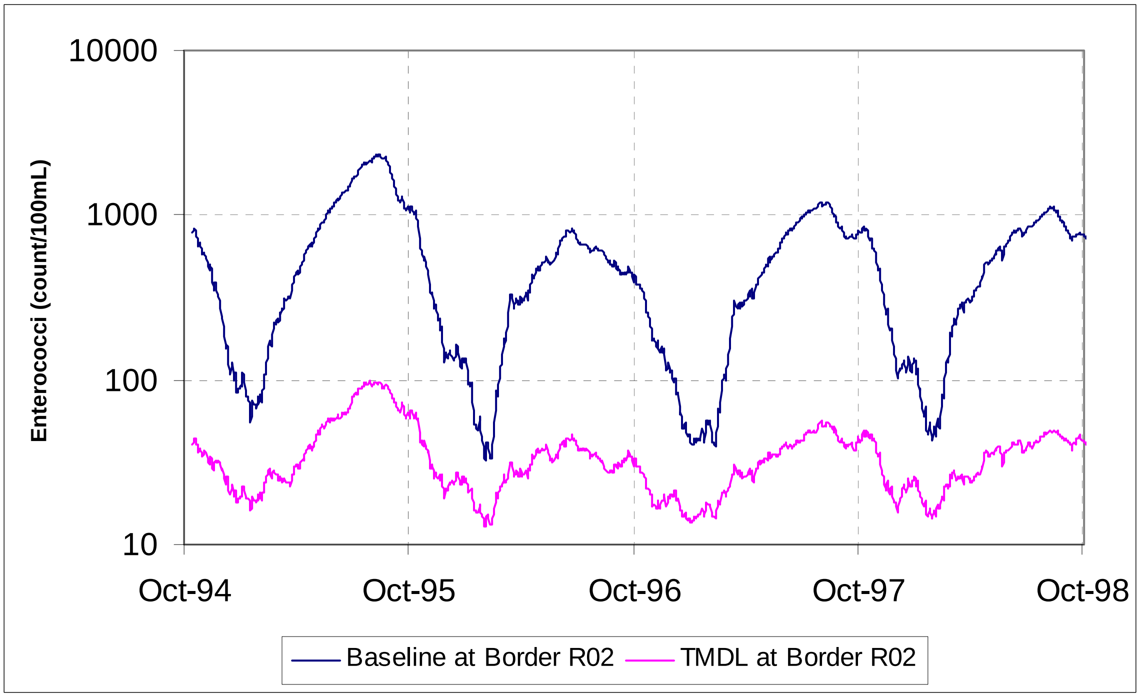


Figure 3. Baseline and TMDL allocation, Red Clay Creek at PA-DE border.

Figure 4. Baseline and TMDL allocation, Christina River subbasin C02.

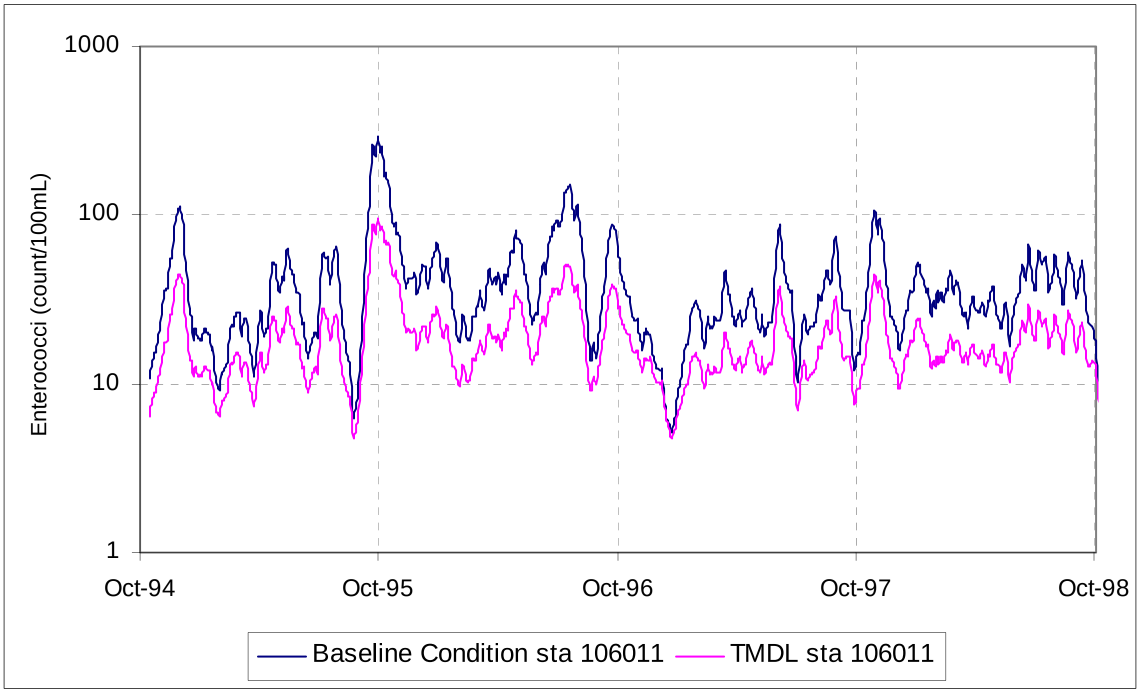


Figure 5. Baseline and TMDL allocation, tidal Christina River (EFDC model results).

Appendix K
Reference Watershed Approach for Siltation and Suspended Solids TMDLs in the Christina River Basin

TMDL development requires the identification of impairment causes and the establishment of numeric endpoints that will allow for the attainment of designated uses and water quality criteria. Numeric endpoints represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. Pennsylvania does not currently have in-stream numeric criteria for siltation or suspended solids in their water quality standards. Therefore, a reference watershed approach is proposed to establish numeric endpoints for sediment in the Christina River Basin. This approach is based on selecting a non-impaired watershed (i.e., reference watershed) that shares similar land use, ecoregion, and geomorphological characteristics with the impaired watershed. Stream conditions in the reference watershed are assumed to be representative of the conditions needed for the impaired stream to attain its designated uses. Loading rates for pollutants of concern are determined for impaired and reference watersheds through modeling studies. Both point and nonpoint sources are considered in the analysis of pollutant sources and in watershed modeling. Numeric endpoints are based on reference watershed loadings for pollutants of concern and load reductions necessary to meet these endpoints are determined. TMDL load allocation scenarios are then developed based on an analysis of the degree to which contributing sources can be reasonably reduced.

Impaired Stream Segments

In the Pennsylvania portion of the Christina River Basin there are 67 stream segments on the 303(d) list impaired by siltation and 8 segments impaired by suspended solids. No stream segments in the Delaware portion of the Christina River Basin are on the 303(d) list for sediment-related impairments. Only 14 stream segments are on the 1996 Pennsylvania 303(d) list for siltation and suspended solids impairments (see Table K-1 and Table K-2 as well as Figure K-1). The remaining 61 stream segments with siltation impairments are on the 1998 Pennsylvania 303(d) list (see Table K-3 and Figure K-2). According to the consent decree, TMDLs for the stream segments on the 1996 list are to be completed by April 2005.

Reference Watershed Approach

The reference watershed approach is used to estimate the necessary load reduction of sediment that is required to restore a healthy aquatic community and allow the streams in the impaired watershed to achieve their designated uses. The reference watershed approach is based on determining the current loading rates for the pollutants of interest from a selected unimpaired watershed that has similar physical characteristics (i.e., land use, soils, size, geology) to those of the impaired watershed.

In the reference watershed approach, two pairs of watersheds are used, one attaining its uses and one that is impaired based on biological assessment. Both watersheds must have similar land cover and land use characteristics. Other features such as base geologic formation, soils, percent slope, and geographic ecoregion should be matched to the extent possible. The objective of this process is to reduce the loading rate of sediment in the impaired stream segment to a level equivalent to or slightly lower than the loading rate in the unimpaired reference stream segment. Achieving the sediment loadings recommended in the TMDLs will ensure protection of the designated aquatic life of the impaired watershed.

Considerations for Reference Watershed Selection

Two factors formed the basis for selecting a suitable reference watershed. The first factor was to use a watershed that had been assessed by PA DEP and had been determined to attain water quality standards and meet designated uses. The second factor was to find a watershed that closely resembled the impaired watershed in physical properties such as land cover, land use, physiographic province, size, and geology. This was accomplished by means of screening the 35 subbasins delineated by the USGS in their HSPF modeling effort of the Brandywine Creek watershed (Senior and Koerkle, 2003). The GIS coverage in the HSPF model database included 12 land use categories (see Table K-4).

There are four steps in determining the reference watersheds that were used to derive the target limits for the TMDLs (see Figure K-3). The first step is to locate watersheds that had been recently assessed and were not impaired. Step 2 is to identify a pool of unimpaired watersheds similar in size and geology to the impaired watersheds. Step 3 involves comparing the land cover data of the watersheds and selecting unimpaired watersheds that had land cover characteristics similar to those of the impaired watersheds. Land use distributions were compared on a percentage basis as calculated from HSPF land use input data. It is important to have a good match between the sizes of the reference and impaired watersheds so that reasonable comparisons could be made. As a result, the fourth step is used to resize the reference watersheds to produce reasonable matches to the impaired watersheds.

Once the reference watersheds are selected, their existing sediment loads can be estimated based on the HSPF watershed model simulation. The estimated existing loads will be analyzed and then considered as the endpoints or target limits for the impaired watersheds.

Overall Technical Approach

A reference watershed approach was used to develop siltation and suspended solids TMDLs for the Christina River Basin. The HSPF watershed model was used to simulate sediment loads from potential sources in the impaired and reference subbasins. Numeric endpoints were on the unit-area loading rates that were calculated for the reference watersheds. TMDL allocations were developed for each impaired subbasin based on these endpoints and the results from load allocation scenarios.

Selection of Reference Watersheds

The impaired subbasins in Brandywine Creek, White Clay Creek, and Red Clay Creek watersheds are listed in Table K-5. The subbasins were classified into two watershed types based on land use. The agricultural watershed type included those subbasins with greater than 31% agricultural land use and less than 22% residential-urban land uses. The residential-urban watershed type included the subbasins with more than 22% residential and urban land uses. One impaired subbasin (B04) had a forest-wetland area of over 70% and did not fit either of these two categories.

For the Brandywine Creek watershed, subbasin B25 (Broad Run) is characterized by 26.8% residential-urban land use and was selected as the residential-urban reference subbasin. All the streams in subbasin B25 are attaining their designated uses according to the Pennsylvania DEP online eMapPA GIS (PDEP, 2004). Subbasin B32, characterized by 31.6% agricultural land use and only 14.2% residential-urban land uses, was selected as the agriculture reference subbasin.

For the White Clay Creek watershed, subbasin W10 was selected as the reference subbasin because all of the peripheral tributaries were attaining their designated uses according to the eMapPA GIS.

For the Red Clay Creek watershed, subbasin R06 was selected as the reference subbasin because it was the only Red Clay Creek subbasin in Pennsylvania with no streams listed as impaired on the 303(d) list.

References

PDEP. 2004. Pennsylvania DEP online eMapPA GIS. The web address is: http://www.emappa.dep.state.pa.us/emappawebsite/HTMLDEMO/

Senior and Koerkle. 2003. Simulation of streamflow and water quality in the Brandywine Creek subbasin of the Christina River Basin, Pennsylvania and Delaware, 1994-98. U.S. Geological Survey Water-Resources Investigations Report 02-4279, 207pp.

Table K-1. Pennsylvania streams requiring TMDLs for siltation (1996 303(d) list)

Map ID	Segment ID	Stream Name	DEP 5-digit code	Downstr RM	Upstr RM	Assessment ID	Year listed
Watershed=03H (Brandywine Creek)							
5	64954_0.0_1.06	Unt E. Br. Brandywine Cr.	64954	0.0	1.06	970707-1120-GLW	1996
6	00229_24.5_27.3	E. Br. Brandywine Cr.	00229	24.46	27.3	970707-1120-GLW	1996
7	00371_0.0_1.46	Unt E. Br. Brandywine Cr.	00371	0.0	1.46	970707-1120-GLW	1996
8	00372_0.0_0.72	Unt E. Br. Brandywine Cr.	00372	0.0	0.72	970707-1120-GLW	1996
20	00085_10.52_16.4	W. Br. Brandywine Cr.	00085	10.52	16.4	19970925-1348-GLW	1996
Watershed=03I (White Clay Creek and Red Clay Creek)							
65	00465_0.0_7.78	W. Br. White Clay Cr.	00465	0.0	7.78	9408	1996

Table K-2. Pennsylvania streams requiring TMDLs for suspended solids (1996 303(d) list)

Map ID	Segment ID	Stream Name	DEP 5-digit code	Downstr RM	Upstr RM	Assessment ID	Year listed
Watershed=03I (White Clay Creek and Red Clay Creek)							
SS1	00475_0.0_1.09	Indian Run	00475	0.0	1.09	115	1996
SS2	00462_2.56_14.08	Mid. Br. White Clay Cr.	00462	2.56	14.08	115	1996
SS3	00462_6.53_8.76	Unt Mid. Br. White Clay Cr.	00462	6.53	8.76	115B	1996
SS4	00476_0.0_1.56	Unt Mid. Br. White Clay Cr.	00476	0.0	1.56	115	1996
SS5	00477_0.0_1.80	Unt Mid. Br. White Clay Cr.	00477	0.0	1.80	115	1996
SS6	00478_0.0_1.26	Unt Mid. Br. White Clay Cr.	00478	0.0	1.26	115	1996
SS7	00479_0.0_0.63	Unt Mid. Br. White Clay Cr.	00479	0.0	0.63	115	1996
SS8	00480_0.0_0.56	Unt Mid. Br. White Clay Cr.	00480	0.0	0.56	115	1996

Table K-3. Pennsylvania streams requiring TMDLs for siltation (1998 303(d) list).

Map ID	Segment ID	Stream Name	DEP 5-digit code	Downstr RM	Upstr RM	Assessment ID	Year listed
Watershed=03H (Brandywine Creek)							
1	00185_0.0_3.31	Unt Buck Run	00185	0.0	3.31	19970710-1040-GLW	1998
2	00186_0.0_0.91	Unt Buck Run	00186	0.0	0.91	19970710-1040-GLW	1998
3	00187_0.0_1.04	Unt Buck Run	00187	0.0	1.04	970710-1340-GLW	1998
4	00202_0.0_3.62	Sucker Run	00202	0.0	3.62	970930-1437-GLW	1998
4a	00203_0.0_1.62	Unt Sucker Run	00203	0.0	1.62	970930-1437-GLW	1998
4b	00204_0.0_0.87	Unt Sucker Run	00204	0.0	0.87	970930-1437-GLW	1998
4c	00205_0.0_0.67	Unt Sucker Run	00205	0.0	0.67	970930-1437-GLW	1998
9	00076_0.0_3.42	Plum Run	00076	0.0	3.42	971023-1320-GLW	1998
10	00077_0.0_0.73	Unt Plum Run	00077	0.0	0.73	971023-1320-GLW	1998
67	00078_0.0_1.35	Unt Plum Run	00078	0.0	1.35	971023-1320-GLW	1998
11	00079_0.0_1.41	Unt Plum Run	00079	0.0	1.41	971023-1320-GLW	1998
12	00080_0.0_0.18	Unt Plum Run	00080	0.0	0.18	971023-1320-GLW	1998
13	00053_0.0_1.16	Pocopson Creek	00053	0.0	1.16	971021-1108-GLW	1998
14	00054_0.0_0.49	Unt Pocopson Creek	00054	0.0	0.49	971021-1108-GLW	1998
15	00071_0.0_2.22	Radley Run	00071	0.0	2.22	971024-1120-GLW	1998
16	00072_0.0_0.94	Unt Radley Run	00072	0.0	0.94	971024-1120-GLW	1998
17	00236_0.0_2.34	Taylor Run	00236	0.0	2.34	971006-1127-GLW	1998
18	00237_0.0_1.08	Unt Taylor Run	00237	0.0	1.08	971006-1127-GLW	1998
19	00238_0.0_0.34	Unt Taylor Run	00238	0.0	0.34	971006-1127-GLW	1998
21	00085_28.4_31.4	W. Br. Brandywine Cr.	00085	28.4	31.4	970618-1118-GLW	1998
22	00085_31.4_32.9	W. Br. Brandywine Cr.	00085	31.4	32.9	970618-1340-GLW	1998
23	00224_0.0_4.58	Unt W. Br. Brandywine Cr.	00224	0.0	4.58	970619-1222-GLW	1998
24	00224_4.58_7.16	Unt W. Br. Brandywine Cr.	00224	4.58	7.16	970619-1345-GLW	1998
25	00225_0.0_0.92	Unt W. Br. Brandywine Cr.	00225	0.0	0.92	970619-1222-GLW	1998
26	00226_0.0_1.41	Unt W. Br. Brandywine Cr.	00226	0.0	1.41	970619-1345-GLW	1998
27	00227_0.0_1.31	Unt W. Br. Brandywine Cr.	00227	0.0	1.31	970618-1340-GLW	1998
28	00228_0.0_0.78	Unt W. Br. Brandywine Cr.	00228	0.0	0.78	970618-1340-GLW	1998
Watershed=03I (White Clay Creek and Red Clay Creek)							
29	00434_0.24_3.49	Broad Run	00434	0.24	3.49	971029-1445-ACW	1998
30	00436_0.0_0.85	Unt Broad Run	00436	0.0	0.85	971029-1445-ACW	1998
31	00393_0.50_0.97	Bucktoe Creek	00393	0.50	0.97	971218-1300-ACW	1998
32	00394_0.0_1.12	Unt Bucktoe Creek	00394	0.0	1.12	971218-1300-ACW	1998
33	00395_0.0_1.09	Unt Bucktoe Creek	00395	0.0	1.09	971218-1300-ACW	1998
34	00413_0.0_5.29	E. Br. Red Clay Cr.	00413	0.0	5.29	971023-1050-MRB	1998
35	00414_0.03_3.28	Unt E. Br. Red Clay Cr.	00414	0.03	3.28	971204-1400-ACW	1998
36	00418_0.0_0.84	Unt E. Br. Red Clay Cr.	00418	0.0	0.84	971204-1400-ACW	1998
37	00419_0.0_1.24	Unt E. Br. Red Clay Cr.	00419	0.0	1.24	971203-1050-MRB	1998
38	00432_0.0_3.1	E. Br. White Clay Cr.	00432	0.0	3.1	971113-1335-GLW	1998
39	00432_3.1_5.77	E. Br. White Clay Cr.	00432	3.1	5.77	970506-1320-MRB	1998

Map ID	Segment ID	Stream Name	DEP 5-digit code	Downstr RM	Upstr RM	Assessment ID	Year listed
40	00432_9.47_10.0	E. Br. White Clay Cr.	00432	9.47	10.0	971119-1116-GLW	1998
41	00438_0.0_0.62	Unt E. Br. White Clay Cr.	00438	0.0	0.62	970506-1320-MRB	1998
42	00439_0.0_0.67	Unt E. Br. White Clay Cr.	00439	0.0	0.67	970506-1320-MRB	1998
43	00443_0.0_0.71	Unt E. Br. White Clay Cr.	00443	0.0	0.71	970506-1320-MRB	1998
44	00444_0.0_0.71	Unt E. Br. White Clay Cr.	00444	0.0	0.71	970506-1320-MRB	1998
45	00445_0.0_2.44	Unt E. Br. White Clay Cr.	00445	0.0	2.44	970508-1430-ACE	1998
46	00446_0.0_0.5	Unt E. Br. White Clay Cr.	00446	0.0	0.5	970506-1320-MRB	1998
47	00447_0.0_0.77	Unt E. Br. White Clay Cr.	00447	0.0	0.77	970506-1320-MRB	1998
48	00448_2.49_2.85	Unt E. Br. White Clay Cr.	00448	2.49	2.85	970409-1130-MRB	1998
49	00450_0.0_0.25	Unt E. Br. White Clay Cr.	00450	0.0	0.25	970409-1130-MRB	1998
50	00454_0.0_5.4	Unt E. Br. White Clay Cr.	00454	0.0	5.4	971120-1331-GLW	1998
51	00455_0.0_2.52	Unt E. Br. White Clay Cr.	00455	0.0	2.52	971120-1331-GLW	1998
52	00456_0.0_0.22	Unt E. Br. White Clay Cr.	00456	0.0	0.22	971120-1331-GLW	1998
53	00440_0.0_1.52	Egypt Run	00440	0.0	1.52	970508-1245-ACE	1998
54	00441_0.0_1.38	Unt Egypt Run	00441	0.0	1.38	970508-1245-ACE	1998
55	00442_0.0_0.76	Unt Egypt Run	00442	0.0	0.76	970508-1245-ACE	1998
56	63874_0.0_1.7	Trout Run	63874	0.0	1.7	970506-1425-MRB	1998
57	63875_0.0_0.82	Unt Trout Run	63875	0.0	0.82	970506-1425-MRB	1998
58	63876_0.0_0.21	Unt Trout Run	63876	0.0	0.21	970506-1425-MRB	1998
59	00435_0.0_1.39	Walnut Run	00435	0.0	1.39	971209-1445-ACW	1998
60	00391_0.0_4.6	W. Br. Red Clay Cr.	00391	0.0	4.6	971023-1145-MRB	1998
61	00396_0.0_1.8	Unt W. Br. Red Clay Cr.	00396	0.0	1.8	971023-1315-MRB	1998
66	00373_1.85_3.26	White Clay Creek	00373	1.85	3.26	971216-1230-GLW	1998

Table K-4. Land-use categories used in HSPF models for Christina River Basin.

Land-use category for HSPF model		**Description**
Pervious	Residential-septic	Residential land not within a sewer service area
	Residential-sewer	Residential land within a sewer service area
	Urban	Commercial, industrial, institutional, and transportation uses
	Agricultural-livestock	Predominantly mixed agricultural activities of dairy cows, pasture, and other livestock operations
	Agricultural-rowcrop	Predominantly row crop cultivation (corn, soybean, alfalfa), may include some hay or pasture land
	Agricultural-mushroom	Mushroom-growing activities including compost preparation, mushroom-house operations, spent compost processing
	Open	Recreational and other open land not used for agricultural
	Forested	Predominantly forested land
	Wetlands/water	Wetlands and open water
	Undesignated	Land use not defined
Impervious	Residential	Impervious residential land
	Urban	Impervious commercial, industrial, and other urban land

Table K-5. Land-use characteristics of impaired subbasins and reference watersheds.

HSPF Subbasin	Area (sq.mi.)	Land uses (percent) Residential-Urban	Agriculture	Forested-Wetland	Watershed Type
Subbasins impaired by siltation in Brandywine Creek watershed:					
B01	18.39	7.9	68.1	20.6	Agriculture
B04	0.80	14.3	14.9	70.5	Mainly Forest
B05	8.82	38.6	19.1	36.3	Residential-Urban
B06	8.06	22.7	39.6	35.9	Residential-Urban
B09	14.68	8.3	54.0	35.4	Agriculture
B14	12.92	32.3	31.9	31.2	Residential-Urban
B15	10.36	33.6	40.7	17.8	Residential-Urban
B20	25.54	13.3	58.8	25.9	Agriculture
B31	9.19	26.8	48.8	22.4	Residential-Urban
Subbasins impaired by siltation in White Clay Creek watershed:					
W01	10.23	19.4	51.8	26.2	Agriculture
W02	9.51	16.7	63.4	17.9	Agriculture
W03	6.35	18.3	44.7	36.4	Agriculture
W04	6.20	14.1	57.5	24.0	Agriculture
W06	8.57	5.4	67.5	22.0	Agriculture
W07	1.37	16.8	62.0	19.0	Agriculture
W08	7.47	14.6	50.4	32.9	Agriculture
W09	6.85	31.1	32.7	33.3	Residential-Urban
Subbasins impaired by siltation in Red Clay Creek watershed:					
R01	10.08	18.2	58.6	18.8	Agriculture
R02	7.39	15.2	58.4	25.4	Agriculture
R03	9.90	21.4	47.3	23.1	Agriculture
Residential-Urban Reference Subbasin for Brandywine Creek watershed:					
B25	5.83	26.8	40.7	30.5	
Agricultural Reference Subbasin for Brandywine Creek watershed:					
B32	4.66	14.2	31.6	53.0	
Reference Subbasin for White Clay Creek watershed:					
W10	3.58	18.8	27.1	53.7	
Reference Subbasin for Red Clay Creek watershed:					
R06	7.10	27.0	42.4	25.2	

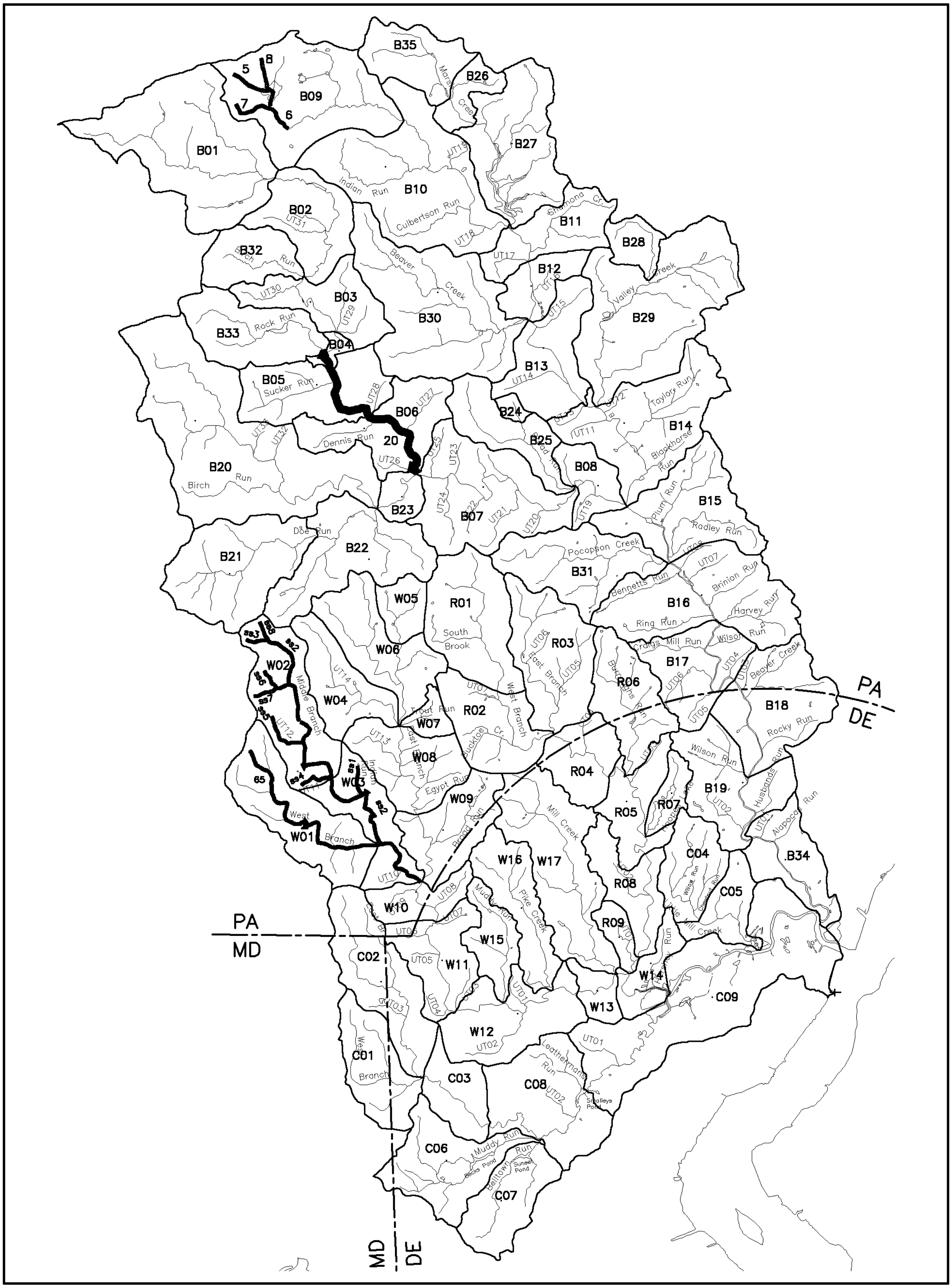


Figure K-1. Christina River Basin, sediment impaired waters on 1996 303(d) list.

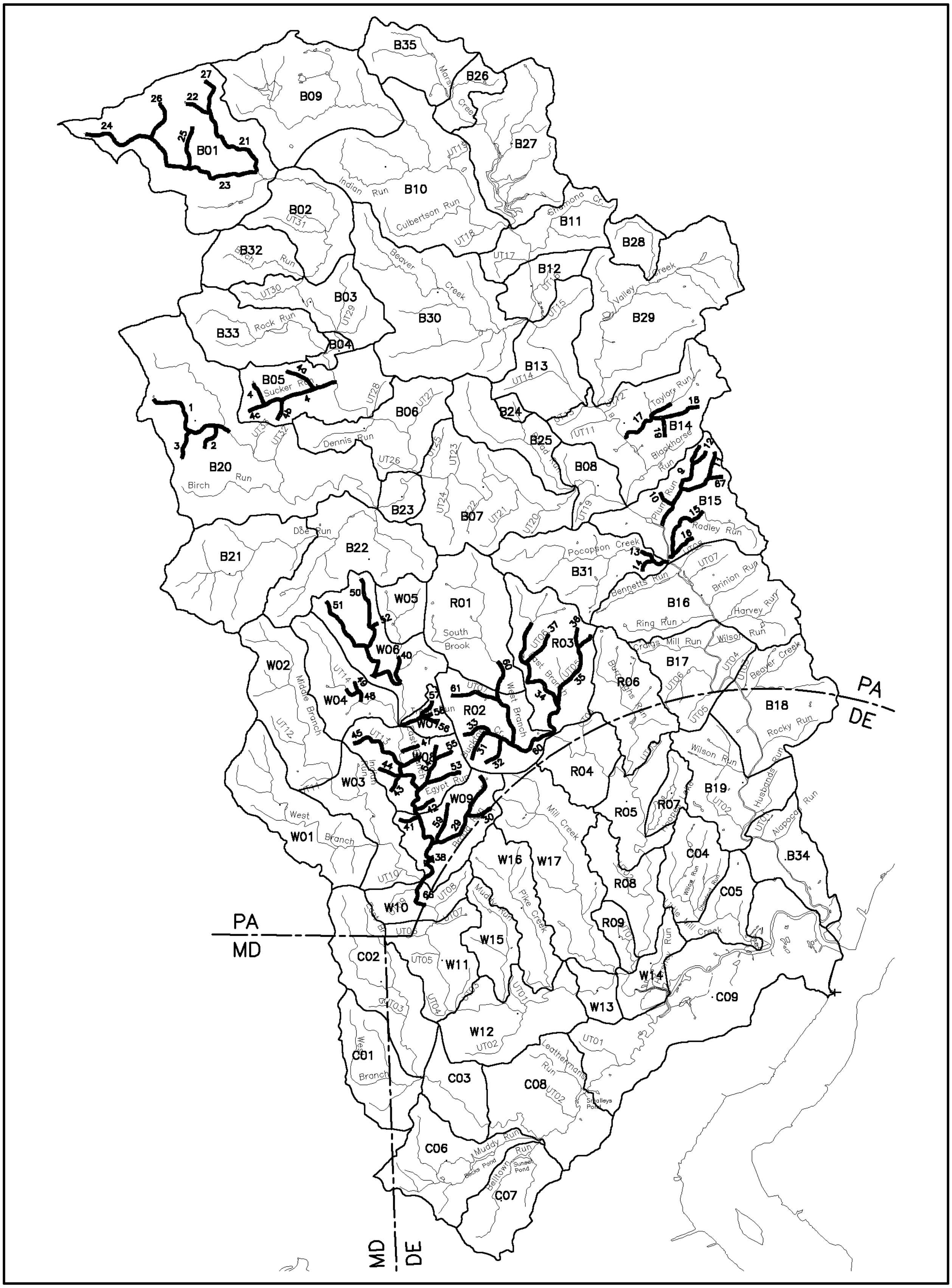


Figure K-2. Christina River Basin, sediment impaired waters on 1998 303(d) list.

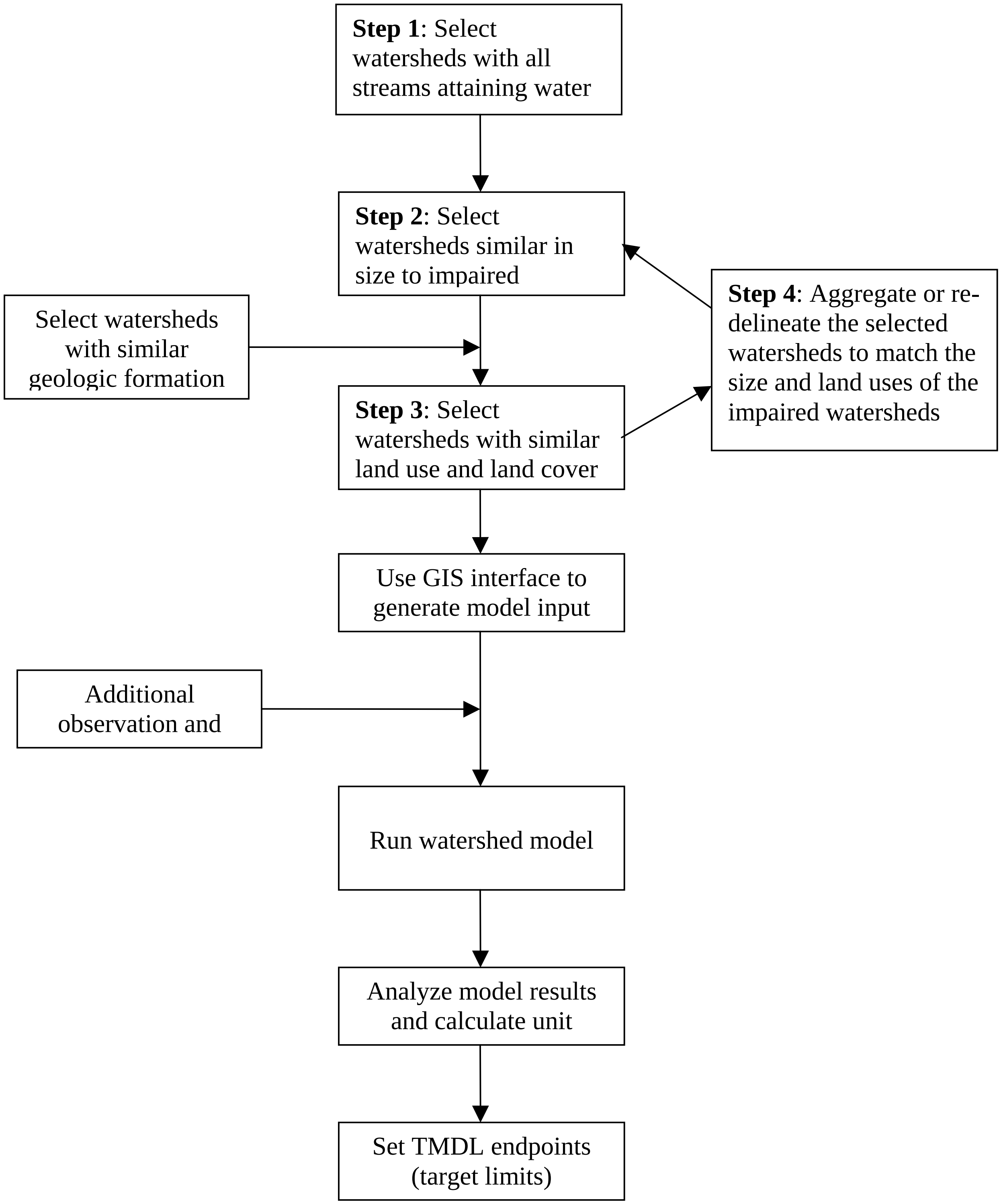


Figure K-3. Reference waterhsed approach for derivation of TMDL target limits.

Appendix L

Land Use Areas for MS4 Municipalities in Chester County, PA

Table L-1. Land Use Areas (acres) for MS4 Municipalities in Brandywine Creek Watershed.

Subbasin	MS4 Municipality	Residential	Agriculture	OpenLand	Forest	Water	Urban	MS4Total	Subbasin Total	MS4Ratio
1	HONEY BROOK BORO	175.55	117.03	0.00	0.00	0.00	19.51	312.08	11766.82	0.0265
1	HONEY BROOK TWP	429.11	6612.23	0.00	1501.89	19.51	370.60	8933.33	11766.82	0.7592
1	WEST CALN TWP	78.02	0.00	0.00	370.60	0.00	19.51	468.12	11766.82	0.0398
2	HONEY BROOK TWP	253.57	78.02	0.00	819.21	0.00	19.51	1170.31	4720.88	0.2479
2	WEST BRANDYWINE TWP	448.62	663.17	0.00	741.19	19.51	78.02	1950.51	4720.88	0.4132
2	WEST CALN TWP	351.09	624.16	19.51	585.15	19.51	19.51	1618.92	4720.88	0.3429
3	COATESVILLE CITY	0.00	0.00	0.00	39.01	0.00	0.00	39.01	4324.94	0.0090
3	VALLEY TWP	19.51	58.52	0.00	58.52	0.00	58.52	195.05	4324.94	0.0451
3	WEST BRANDYWINE TWP	760.70	702.18	0.00	663.17	0.00	19.51	2145.56	4324.94	0.4961
3	WEST CALN TWP	253.57	487.63	19.51	643.67	19.51	39.01	1462.88	4324.94	0.3382
4	COATESVILLE CITY	19.51	0.00	0.00	175.55	0.00	39.01	234.06	519.99	0.4501
4	VALLEY TWP	19.51	39.01	0.00	234.06	0.00	19.51	312.08	519.99	0.6002
5	COATESVILLE CITY	487.63	0.00	19.51	117.03	0.00	312.08	936.24	5644.14	0.1659
5	EAST FALLOWFIELD TWP	136.54	331.59	0.00	565.65	0.00	156.04	1189.81	5644.14	0.2108
5	MODENA BORO	19.51	0.00	0.00	39.01	19.51	0.00	78.02	5644.14	0.0138
5	SADSBURY TWP	19.51	58.52	0.00	19.51	0.00	19.51	117.03	5644.14	0.0207
5	VALLEY TWP	331.59	585.15	19.51	604.66	19.51	468.12	2028.53	5644.14	0.3594
6	EAST FALLOWFIELD TWP	916.74	1404.37	39.01	1443.38	0.00	136.54	3940.03	5159.73	0.7636
6	MODENA BORO	19.51	39.01	0.00	39.01	0.00	58.52	156.04	5159.73	0.0302
6	NEWLIN TWP	0.00	58.52	0.00	175.55	0.00	39.01	273.07	5159.73	0.0529
6	WEST BRADFORD TWP	136.54	351.09	0.00	234.06	0.00	0.00	721.69	5159.73	0.1399
7	EAST MARLBOROUGH TWP	39.01	429.11	0.00	156.04	0.00	0.00	624.16	8616.54	0.0724
7	NEWLIN TWP	292.58	2867.25	0.00	2594.18	97.53	273.07	6124.60	8616.54	0.7108
7	POCOPSON TWP	39.01	195.05	0.00	117.03	0.00	19.51	370.60	8616.54	0.0430
7	WEST BRADFORD TWP	195.05	507.13	0.00	546.14	0.00	175.55	1423.87	8616.54	0.1652
8	EAST BRADFORD TWP	78.02	429.11	0.00	214.56	19.51	0.00	741.19	2314.42	0.3203
8	POCOPSON TWP	0.00	526.64	0.00	195.05	19.51	0.00	741.19	2314.42	0.3203
8	WEST BRADFORD TWP	136.54	487.63	0.00	195.05	0.00	39.01	858.22	2314.42	0.3708
9	HONEY BROOK TWP	292.58	2711.21	0.00	916.74	273.07	39.01	4232.60	9397.55	0.4504
9	WALLACE TWP	39.01	97.53	0.00	234.06	0.00	39.01	409.61	9397.55	0.0436
10	EAST BRANDYWINE TWP	819.21	819.21	19.51	819.21	19.51	19.51	2516.16	11721.04	0.2147
10	HONEY BROOK TWP	58.52	19.51	0.00	58.52	39.01	39.01	214.56	11721.04	0.0183
10	UPPER UWCHLAN TWP	97.53	195.05	0.00	195.05	0.00	19.51	507.13	11721.04	0.0433
10	WALLACE TWP	702.18	1794.47	58.52	2633.19	0.00	175.55	5363.90	11721.04	0.4576
10	WEST BRANDYWINE TWP	409.61	819.21	19.51	741.19	19.51	78.02	2087.04	11721.04	0.1781
11	EAST BRANDYWINE TWP	214.56	331.59	0.00	546.14	0.00	0.00	1092.29	4039.89	0.2704
11	UPPER UWCHLAN TWP	0.00	19.51	0.00	78.02	0.00	0.00	97.53	4039.89	0.0241
11	UWCHLAN TWP	663.17	916.74	39.01	936.24	0.00	253.57	2808.73	4039.89	0.6952
12	DOWNINGTOWN BORO	156.04	39.01	39.01	39.01	19.51	58.52	351.09	2369.53	0.1482

12	EAST BRANDYWINE TWP	156.04	58.52	0.00	136.54	19.51	19.51	390.10	2369.53	0.1646
12	EAST CALN TWP	195.05	39.01	0.00	292.58	0.00	19.51	546.14	2369.53	0.2305
12	UWCHLAN TWP	312.08	0.00	0.00	331.59	0.00	19.51	663.17	2369.53	0.2799
13	DOWNINGTOWN BORO	253.57	136.54	0.00	117.03	0.00	234.06	741.19	5084.19	0.1458
13	EAST BRADFORD TWP	39.01	136.54	0.00	409.61	19.51	0.00	604.66	5084.19	0.1189
13	EAST CALN TWP	273.07	234.06	117.03	351.09	0.00	214.56	1189.81	5084.19	0.2340
13	WEST BRADFORD TWP	702.18	253.57	0.00	1404.37	0.00	156.04	2516.16	5084.19	0.4949
14	EAST BRADFORD TWP	1072.78	1931.00	97.53	1131.30	97.53	156.04	4486.17	8268.16	0.5426
14	WEST BRADFORD TWP	97.53	526.64	0.00	487.63	0.00	78.02	1189.81	8268.16	0.1439
14	WEST GOSHEN TWP	663.17	214.56	19.51	838.72	19.51	195.05	1950.51	8268.16	0.2359
15	BIRMINGHAM TWP	546.14	741.19	117.03	136.54	19.51	136.54	1696.94	6631.34	0.2559
15	EAST BRADFORD TWP	526.64	604.66	19.51	351.09	0.00	117.03	1618.92	6631.34	0.2441
15	PENNSBURY TWP	0.00	19.51	0.00	0.00	0.00	0.00	19.51	6631.34	0.0029
15	POCOPSON TWP	136.54	663.17	0.00	234.06	97.53	58.52	1189.81	6631.34	0.1794
15	THORNBURY TWP	0.00	331.59	0.00	97.53	0.00	19.51	448.62	6631.34	0.0677
15	WEST GOSHEN TWP	253.57	0.00	58.52	78.02	0.00	19.51	409.61	6631.34	0.0618
16	BIRMINGHAM TWP	585.15	780.20	0.00	780.20	39.01	58.52	2243.09	8996.74	0.2493
16	KENNETT TWP	351.09	214.56	0.00	117.03	0.00	58.52	741.19	8996.74	0.0824
16	PENNSBURY TWP	975.25	760.70	0.00	1228.82	39.01	78.02	3081.80	8996.74	0.3425
16	THORNBURY TWP	0.00	0.00	0.00	19.51	0.00	0.00	19.51	8996.74	0.0022
17	KENNETT TWP	78.02	0.00	0.00	58.52	0.00	0.00	136.54	4804.91	0.0284
17	PENNSBURY TWP	370.60	936.24	0.00	1326.35	58.52	0.00	2691.70	4804.91	0.5602
18	PENNSBURY TWP	0.00	19.51	0.00	19.51	19.51	0.00	58.52	6636.33	0.0088
20	EAST FALLOWFIELD TWP	585.15	2165.07	0.00	1111.79	19.51	117.03	3998.54	16344.14	0.2446
20	HIGHLAND TWP	136.54	3744.98	0.00	1482.39	19.51	234.06	5617.47	16344.14	0.3437
20	PARKESBURG BORO	429.11	97.53	0.00	97.53	0.00	136.54	760.70	16344.14	0.0465
20	SADSBURY TWP	507.13	2048.03	0.00	975.25	0.00	312.08	3842.50	16344.14	0.2351
20	WEST CALN TWP	58.52	273.07	0.00	195.05	0.00	19.51	546.14	16344.14	0.0334
21	HIGHLAND TWP	78.02	2594.18	0.00	253.57	19.51	58.52	3003.78	7074.39	0.4246
22	EAST FALLOWFIELD TWP	0.00	19.51	0.00	0.00	0.00	0.00	19.51	7013.14	0.0028
22	EAST MARLBOROUGH TWP	0.00	234.06	0.00	97.53	0.00	0.00	331.59	7013.14	0.0473
23	EAST FALLOWFIELD TWP	0.00	351.09	0.00	273.07	0.00	0.00	624.16	1245.87	0.5010
23	NEWLIN TWP	0.00	331.59	0.00	292.58	0.00	0.00	624.16	1245.87	0.5010
24	WEST BRADFORD TWP	390.10	19.51	0.00	0.00	0.00	0.00	409.61	383.68	1.0676
25	NEWLIN TWP	39.01	39.01	0.00	0.00	0.00	0.00	78.02	3733.70	0.0209
25	WEST BRADFORD TWP	936.24	1443.38	19.51	1111.79	0.00	175.55	3686.46	3733.70	0.9873
26	WALLACE TWP	78.02	97.53	0.00	273.07	0.00	39.01	487.63	1673.35	0.2914
27	UPPER UWCHLAN TWP	1404.37	1306.84	78.02	1599.42	565.65	273.07	5227.36	6837.84	0.7645
27	UWCHLAN TWP	0.00	0.00	0.00	39.01	0.00	0.00	39.01	6837.84	0.0057
27	WALLACE TWP	175.55	195.05	0.00	292.58	19.51	19.51	702.18	6837.84	0.1027
28	UWCHLAN TWP	741.19	19.51	39.01	136.54	0.00	58.52	994.76	1537.60	0.6470
29	EAST BRADFORD TWP	526.64	448.62	39.01	1228.82	0.00	97.53	2340.61	11653.36	0.2009
29	EAST CALN TWP	39.01	39.01	78.02	214.56	39.01	273.07	682.68	11653.36	0.0586
29	UWCHLAN TWP	156.04	19.51	0.00	78.02	0.00	19.51	273.07	11653.36	0.0234
29	WEST GOSHEN TWP	409.61	78.02	0.00	195.05	0.00	39.01	721.69	11653.36	0.0619
30	DOWNINGTOWN BORO	214.56	19.51	0.00	39.01	0.00	19.51	292.58	11568.11	0.0253
30	EAST BRANDYWINE TWP	936.24	1404.37	0.00	780.20	0.00	136.54	3257.35	11568.11	0.2816

30	EAST FALLOWFIELD TWP	39.01	117.03	0.00	39.01	0.00	19.51	214.56	11568.11	0.0185
30	WEST BRADFORD TWP	273.07	214.56	0.00	546.14	0.00	39.01	1072.78	11568.11	0.0927
30	WEST BRANDYWINE TWP	351.09	1287.34	39.01	507.13	0.00	39.01	2223.58	11568.11	0.1922
31	EAST MARLBOROUGH TWP	663.17	799.71	78.02	253.57	0.00	19.51	1813.97	5883.50	0.3083
31	NEWLIN TWP	39.01	468.12	0.00	97.53	0.00	19.51	624.16	5883.50	0.1061
31	PENNSBURY TWP	58.52	351.09	0.00	136.54	0.00	0.00	546.14	5883.50	0.0928
31	POCOPSON TWP	780.20	1365.36	0.00	741.19	19.51	78.02	2984.28	5883.50	0.5072
32	WEST CALN TWP	429.11	1033.77	0.00	1599.42	0.00	58.52	3120.81	2981.99	1.0466
33	SADSBURY TWP	39.01	19.51	0.00	19.51	0.00	0.00	78.02	5139.05	0.0152
33	VALLEY TWP	214.56	331.59	19.51	487.63	0.00	175.55	1228.82	5139.05	0.2391
33	WEST CALN TWP	643.67	1794.47	97.53	1014.26	117.03	117.03	3783.99	5139.05	0.7363
35	WALLACE TWP	58.52	156.04	0.00	351.09	0.00	39.01	604.66	3713.47	0.1628

Note: MS4 Total = total land area in MS4 municipality
Subbasin Total = total land area of HSPF subbasin
MS4 Ratio = MS4 Total / Subbasin Total

Table L-2. Land Use Areas (acres) for MS4 Municipalities in Red Clay Creek Watershed.

Subbasin	MS4 Municipality	Residential	Agriculture	OpenLand	Forest	Water	Urban	MS4 Total	Subbasin Total	MS4Ratio
1	EAST MARLBOROUGH TWP	565.65	2847.74	39.01	838.72	19.51	156.04	4466.67	6448.43	0.6927
1	KENNETT SQUARE BORO	136.54	97.53	19.51	0.00	0.00	97.53	351.09	6448.43	0.0544
1	KENNETT TWP	58.52	78.02	19.51	78.02	0.00	97.53	331.59	6448.43	0.0514
1	NEW GARDEN TWP	117.03	331.59	0.00	156.04	0.00	97.53	702.18	6448.43	0.1089
2	KENNETT SQUARE BORO	0.00	19.51	0.00	0.00	0.00	0.00	19.51	4727.00	0.0041
2	KENNETT TWP	585.15	624.16	0.00	643.67	0.00	0.00	1852.98	4727.00	0.3920
2	NEW GARDEN TWP	234.06	1891.99	0.00	604.66	0.00	136.54	2867.25	4727.00	0.6066
3	EAST MARLBOROUGH TWP	546.14	1345.85	234.06	312.08	0.00	156.04	2594.18	6333.99	0.4096
3	KENNETT SQUARE BORO	175.55	39.01	0.00	58.52	0.00	39.01	312.08	6333.99	0.0493
3	KENNETT TWP	643.67	1677.44	0.00	916.74	19.51	136.54	3393.89	6333.99	0.5358
4	KENNETT TWP	195.05	195.05	0.00	292.58	0.00	0.00	682.68	3272.23	0.2086
6	KENNETT TWP	624.16	916.74	19.51	897.23	0.00	97.53	2555.17	4543.71	0.5624
6	PENNSBURY TWP	78.02	78.02	0.00	58.52	0.00	78.02	292.58	4543.71	0.0644

Note: MS4 Total = total land area in MS4 municipality
Subbasin Total = total land area of HSPF subbasin
MS4 Ratio = MS4 Total / Subbasin Total

Table L-3. Land Use Areas (acres) for MS4 Municipalities in White Clay Creek Watershed.

Subbasin	MS4 Municipality	Residential	Agriculture	OpenLand	Forest	Water	Urban	MS4 Total	Subbasin Total	MS4Ratio
1	FRANKLIN TWP	331.59	1423.87	0.00	955.75	0.00	136.54	2847.74	6537.83	0.4356
1	LONDON BRITAIN TWP	78.02	136.54	0.00	214.56	0.00	0.00	429.11	6537.83	0.0656
1	NEW LONDON TWP	507.13	1014.26	0.00	409.61	0.00	156.04	2087.04	6537.83	0.3192
1	PENN TWP	175.55	682.68	0.00	214.56	0.00	19.51	1092.29	6537.83	0.1671
2	LONDON GROVE TWP	468.12	1618.92	19.51	507.13	19.51	19.51	2652.69	6089.44	0.4356
2	NEW LONDON TWP	39.01	58.52	0.00	58.52	0.00	0.00	156.04	6089.44	0.0256
2	PENN TWP	273.07	1306.84	0.00	409.61	19.51	39.01	2048.03	6089.44	0.3363
2	WEST GROVE BORO	156.04	19.51	0.00	0.00	0.00	58.52	234.06	6089.44	0.0384
3	FRANKLIN TWP	234.06	838.72	0.00	585.15	0.00	0.00	1657.93	4063.37	0.4080
3	LONDON BRITAIN TWP	448.62	624.16	0.00	682.68	19.51	0.00	1774.96	4063.37	0.4368
3	LONDON GROVE TWP	195.05	253.57	0.00	195.05	0.00	19.51	663.17	4063.37	0.1632
4	AVONDALE BORO	39.01	19.51	0.00	19.51	0.00	0.00	78.02	3971.00	0.0196
4	LONDON GROVE TWP	312.08	2145.56	19.51	916.74	19.51	136.54	3549.93	3971.00	0.8940
4	WEST GROVE BORO	58.52	39.01	19.51	39.01	0.00	39.01	195.05	3971.00	0.0491
5	LONDON GROVE TWP	0.00	136.54	0.00	58.52	0.00	0.00	195.05	1705.95	0.1143
6	AVONDALE BORO	58.52	0.00	0.00	58.52	0.00	0.00	117.03	5484.38	0.0213
6	LONDON GROVE TWP	39.01	1891.99	0.00	351.09	0.00	39.01	2321.11	5484.38	0.4232
6	NEW GARDEN TWP	58.52	448.62	136.54	273.07	0.00	97.53	1014.26	5484.38	0.1849
7	AVONDALE BORO	19.51	58.52	0.00	19.51	0.00	19.51	117.03	877.92	0.1333
7	NEW GARDEN TWP	136.54	546.14	0.00	97.53	19.51	39.01	838.72	877.92	0.9553
8	FRANKLIN TWP	117.03	351.09	0.00	136.54	0.00	0.00	604.66	4776.15	0.1266
8	LONDON GROVE TWP	214.56	624.16	39.01	702.18	0.00	19.51	1599.42	4776.15	0.3349
8	NEW GARDEN TWP	390.10	1306.84	0.00	780.20	0.00	58.52	2535.66	4776.15	0.5309
9	FRANKLIN TWP	0.00	19.51	0.00	0.00	0.00	0.00	19.51	4386.93	0.0044
9	LONDON BRITAIN TWP	273.07	468.12	0.00	643.67	19.51	0.00	1404.37	4386.93	0.3201
9	NEW GARDEN TWP	546.14	877.73	0.00	604.66	39.01	195.05	2262.59	4386.93	0.5158
10	LONDON BRITAIN TWP	292.58	429.11	0.00	604.66	0.00	19.51	1345.85	2303.61	0.5842
11	LONDON BRITAIN TWP	58.52	117.03	0.00	156.04	0.00	19.51	351.09	4175.09	0.0841
17	KENNETT TWP	19.51	175.55	0.00	19.51	0.00	0.00	214.56	8320.77	0.0258
17	NEW GARDEN TWP	0.00	58.52	0.00	0.00	0.00	0.00	58.52	8320.77	0.0070

Note: MS4 Total = total land area in MS4 municipality
Subbasin Total = total land area of HSPF subbasin
MS4 Ratio = MS4 Total / Subbasin Total

Appendix M

EPA Bacteria Indicator Tool
User's Guide

United States Environmental Protection Agency

Office of Water 4305

EPA-823-B-01-003
March 2000

Bacterial Indicator Tool

User's Guide

Bacterial Indicator Tool
User's Guide
March 31, 2000

INTRODUCTION

The Bacterial Indicator Tool is a spreadsheet that estimates the bacteria contribution from multiple sources. Currently, the tool is enabled for fecal coliform. However, the tool could be adapted for other bacterial indicators, such as *E. coli*, if the necessary bacteria production information is available. Output from the tool is used as input to WinHSPF and the Hydrological Simulation Program Fortran (HSPF) water quality model within BASINS. The tool estimates the monthly accumulation rate of fecal coliform bacteria on four land uses (cropland, forest, built-up, and pastureland), as well as the asymptotic limit for that accumulation should no washoff occur. The tool also estimates the direct input of fecal coliform bacteria to streams from grazing agricultural animals and failing septic systems. The Bacterial Indicator Tool was developed to provide starting values for model input, however a thorough calibration of the model is still recommended.

The Bacterial Indicator Tool is based on a modeling study of 10 subwatersheds, composed of four land uses (cropland, forest, built-up, and pastureland). BLUE text found throughout the spreadsheet presents valuable information and assumptions. RED text designates values that should be specified by the user. BLACK text usually presents information that is calculated by the spreadsheet or that should not be changed. The tool contains the following worksheets:

Worksheet Name	Purpose
Land Use	Lists the distributions of built-up land, forestland, cropland, and pastureland in up to 10 subwatersheds.
Animals	Lists the number of agricultural animals in each subwatershed (beef cattle, dairy cattle, swine, chickens, horses, sheep, and other [user-defined]), and the densities of wildlife by land use category (ducks, geese, deer, beaver, raccoons, and other [user-defined]).
Manure Application	Calculates the fraction of the annual manure produced that is available for washoff based on the amount applied to cropland and pastureland in each month and the fraction of manure incorporated into the soil (for hog, beef cattle, dairy cattle, horse, and poultry manure).
Grazing	Lists the days spent confined and grazing for beef cattle, horses, sheep, and other. Beef cattle are assumed to have access to streams while grazing.
References	Lists literature and assumed values for manure content, wildlife densities, and built-up fecal coliform accumulation rates. These values are used in calculations in the remaining worksheets.

Worksheet Name	Purpose
Wildlife	Calculates the fecal coliform bacteria produced by wildlife by land use category.
Cropland	Calculates the monthly rate of accumulation of fecal coliform bacteria on cropland from wildlife, hog, cattle, and poultry manure.
Forest	Calculates the rate of accumulation of fecal coliform bacteria on forestland from wildlife.
Built-up	Calculates the rate of accumulation of fecal coliform bacteria on built-up land using literature values.
Pastureland	Calculates the monthly rate of accumulation of fecal coliform bacteria on pastureland from wildlife, cattle, and horse manure, and cattle, horse, sheep, and other grazing.
Cattle in Streams	Calculates the monthly loading and flow rate of fecal coliform bacteria contributed directly to the stream by beef cattle.
Septics	Calculates the monthly loading and flow rate of fecal coliform bacteria from failing septic systems.
ACQOP&SQOLIM (for land uses)	Summarizes the monthly rate of accumulation of fecal coliform bacteria on the four land uses; calculates the build-up limit for each land use. Provides input paramters for HSPF (ACQOP/MON-ACCUM and SQOLIM/MON-SQOLIM).

The following information must be input by the user:

- Land use distribution for each subwatershed (built-up, forest, cropland, and pastureland, including, to the extent possible, the breakout of built-up land into commercial and services, mixed urban or built-up, residential, and transportation/communications/utilities).
- Agricultural animals in each subwatershed
- Wildlife densities for forest, cropland, and pastureland in the study area (built-up land is assumed not to have wildlife)
- Number of septic systems in the study area
- Number of people served by septic systems in the study area
- Failure rate of septic systems in the study area

Default values are supplied for the following inputs, but they should be modified to reflect patterns in the study watershed:

- Fraction of each manure type that is applied each month
- Fraction of each manure type that is incorporated into the soil
- Time spent grazing and confined by agricultural animals (and in stream for beef cattle only)

Literature values are supplied for the following inputs, but they may be replaced with user values if better information is available for the study watershed:

- Animal waste production rates and fecal coliform bacteria content
- Fecal coliform bacteria accumulation rates for built-up land uses
- Raw sewage fecal coliform bacteria content and per capita waste production

The remainder of this document describes the purpose and use of each worksheet within the Bacterial Indicator Tool, as well as the input required by the user (if any). The symbol "**U**" indicates that user input is required in the sheet being described; the symbol " - " indicates that no input is needed.

LAND USE

U	User Input Required

The modeled land uses are derived from the original land uses by reassigning the original categories to the corresponding model categories. Only four categories are considered in this tool: Cropland, Forest, Built-up, and Pastureland. Reassign the categories in your existing land use database, and calculate the acres of each of the four model land use categories within each subwatershed. Enter the values in the appropriate cells on the Land Use sheet. Total acres by subwatershed and land use category will be calculated automatically.

ANIMALS

U	User Input Required

Fecal contributions from the animals listed in this worksheet are used to derive loading estimates for all land uses except for built-up. Only manure from cattle, swine, and poultry is assumed to be collected and applied to cropland. Cattle manure is also assumed to be applied to pastureland. Horse manure is assumed to be collected and applied to pastureland only. Manure from cattle, horses, sheep and "other" agricultural animals is assumed to be contributed to pastureland in proportion to time spent grazing. Wildlife densities are provided for all land uses except built-up and are assumed to be the same in all subwatersheds. An "other" category is provided for both agricultural animals and wildlife to allow the user to include animals that are not already available in the tool.

In the absence of site-specific data, the number of agricultural animals present in each subwatershed can be determined using county-level data from the Census of Agriculture (http://www.nass.usda.gov/census/census97/highlights/ag-state.htm). The total number of agricultural animals can be estimated for each subwatershed based on a ratio of subwatershed-level pastureland to county-level pastureland area. For example, assume Subwatershed 1 is located entirely within County A and that County A contains 1000 acres of pastureland and 200 dairy cows. If Subwatershed 1 contains 100 acres of pastureland, this subwatershed is assigned [(200/1000)*100] = 20 dairy cows. Calculate the number of agricultural animals (dairy and beef cattle, swine, chickens, horses, sheep, and "other") in each subwatershed and enter these values in the appropriate cells on the Animals sheet. Totals by subwatershed and animal type will be calculated automatically.

The densities of wildlife are estimated based on the best available information. It is assumed that no wildlife are present on built-up land and that the densities of wildlife on each of the remaining land use types (forest, cropland and pastureland) are the same across all subwatersheds. Enter the density for each form of wildlife (ducks, geese, deer, beaver, raccoons, and "other") on each land use type in animals per square mile. The wildlife densities per acre will be calculated automatically.

MANURE APPLICATION

U	User Input Required

This sheet contains information regarding the land application of waste produced by agricultural animals in the study area. Application of hog manure, cattle manure, horse manure, and poultry litter is considered. The information is presented based on the monthly variability of waste application. The annual production of manure is calculated and then applied each month using the information in this sheet. It is assumed that cattle manure is applied to both cropland and pastureland using the same method. Hog manure and poultry litter are assumed to be applied only to cropland. Horse manure is assumed to be applied only to pastureland.

For each of the four major manure sources (hogs, cattle, horses, and poultry), specify the fraction of the annual manure produced that is applied each month (January through December) and the fraction of the manure applied that is incorporated into the soil. The fraction of manure available for washoff each month for each type of manure will then be calculated automatically. Note that the equation used to calculate the fraction available for runoff can be updated if necessary.

GRAZING

U	User Input Required

This sheet contains information relevant to cattle, horses, sheep, and "other" animals grazing in the study area. Dairy cattle are assumed to be kept only in feedlots. Therefore, all of their waste is used for manure application (divided between cropland and pastureland). Beef cattle are assumed to be kept in feedlots or allowed to graze (depending on the season). When they are grazing, a certain proportion is assumed to have direct access to streams. The grazing time spent in streams actually represents a combination of the number of animals with stream access and the percent of time these animals spend contributing waste directly to the streams. Beef cattle waste is therefore applied as manure to cropland and pastureland, contributed directly to pastureland, or contributed directly to streams (referred to by the tool as Cattle in Streams). Horses are assumed to be either kept in stables or allowed to graze. Horse waste is therefore either applied as manure to pastureland or contributed directly to pastureland; horse manure is not applied to cropland. Sheep are assumed to be allowed to graze year-round. Sheep waste is therefore contributed only directly to pastureland. The purpose of the "other" animal category is to allow you to define the grazing patterns of an agricultural animal not available in the default information. To use this category, you must be sure to enter the number of "other" animals in each subwatershed (on the Animals sheet) and to specify a fecal coliform bacteria production rate for this animal (on the References sheet). "Other" animal waste is contributed directly to pastureland only while grazing.

For cattle, horses, sheep, and "other," enter the fraction of time spent confined each month (from 0, never confined, to 1, always confined). The fraction of time and the number of days per year spent grazing will be calculated automatically. For cattle, you should also specify the fraction of time grazing that is spent in streams. The fraction of time grazing spent in pasture will be calculated automatically.

REFERENCES

-	User Input Required

The data from the References sheet are accessed in the remaining worksheets. Fecal coliform production rates for various animals are presented from several sources, and you may select the source you prefer or enter a value of your own in the "Best Professional Judgement" column. The spreadsheet is set up to use the ASAE values by default. If you prefer to use a different source, be sure to change the values in cells B9 through B23 on the References sheet. To use the "other" agricultural and wildlife animal categories, you must provide the number of "other" animals in each subwatershed (on the Animals sheet) and a fecal coliform bacteria production rate for this animal (on the References sheet). The References sheet also contains fecal coliform accumulation rates for five Built-up land use types. These numbers may also be changed if appropriate.

WILDLIFE

-	User Input Required

This sheet calculates the total fecal coliform bacteria produced by wildlife each day per acre of cropland, pastureland, and forest. This calculation is performed by multiplying the density (animals per acre) of each type of wildlife on each land use by the rate of fecal coliform production for that wildlife type (count per animal per day). The number of fecal coliform bacteria produced is then summed across all wildlife types for each land use to obtain a total wildlife fecal coliform production rate (count per acre per day), which will be used in subsequent sheets.

To use the "other" wildlife category, you must be sure to enter the number of "other" animals in each subwatershed (on the Animals sheet) and to specify a fecal coliform bacteria production rate for this animal (on the References sheet). No user input is required on the Wildlife sheet.

CROPLAND

-	User Input Required

This sheet calculates the total fecal coliform bacteria applied to each acre of cropland by month. The sources of fecal coliform bacteria for cropland are wildlife, hog manure application, cattle manure application, and poultry litter application. No user input is required on the cropland sheet. Chickens and hogs are assumed to be confined all of the time, and their manure is applied only to cropland. Dairy cattle are also assumed to be confined all of the time, and their manure is applied to both cropland and pastureland. Beef cattle are assumed to be either kept in feedlots or allowed to graze, depending on the season. When they are grazing, a certain proportion is assumed to have direct access to streams (as specified in the Grazing sheet.) Beef cattle manure is therefore either applied to cropland and pastureland, contributed directly to pastureland during grazing, or contributed directly to streams (referred to by the tool as Cattle in Streams.)

Wildlife
The fecal coliform bacteria produced by wildlife per acre of cropland is determined for each month as follows:

1. The total wildlife population of each subwatershed is calculated (acres of cropland from the Land Use sheet multiplied by the cropland wildlife density from the Wildlife sheet.)
2. The total daily fecal coliform bacteria load generated by that population is calculated (acres of cropland from the Land Use sheet multiplied by the fecal coliform generated per acre of cropland from the Wildlife sheet).

3. The daily per acre accumulation rate of fecal coliform bacteria from wildlife is calculated by dividing the total load generated by the number of acres of cropland in each subwatershed.

Hog Manure

The fecal coliform bacteria from hog manure applied per acre of cropland is determined for each month as follows:

1. The number of hogs in each subwatershed (from the Animals sheet) is multiplied by the daily fecal coliform production rate per hog (from the References sheet) to obtain the daily hog fecal coliform production rate.
2. The daily rate is then multiplied by 365 to obtain the amount of fecal coliform produced by hogs per year.
3. The fecal coliform bacteria available for washoff is then calculated by multiplying the annual fecal coliform produced by the amount applied and available for washoff in each subwatershed in each month (from the hog manure section of the Manure Application sheet).
4. The monthly total is then divided by the number of days in each month to obtain the daily accumulation rate.
5. Finally, the daily accumulation rate is divided by the number of acres of cropland in each subwatershed to obtain the daily per acre load of fecal coliform bacteria from hog manure.

Cattle Manure

The fecal coliform bacteria from cattle manure applied per acre of cropland is determined for each month as follows:

1. The number of dairy and beef cattle in each subwatershed (from the Animals sheet) is multiplied by the daily fecal coliform production rate per dairy and beef cow (from the References sheet) to obtain the daily dairy and beef cattle fecal coliform production rates.
2. The daily dairy fecal coliform production rate is then multiplied by 365 to obtain the amount of fecal coliform produced by dairy cattle and available for application as manure per year. The daily beef fecal coliform production rate is multiplied by 365 minus the days spent grazing (from the cattle section of the Grazing sheet) to obtain the amount of fecal coliform produced by beef cattle and available for application as manure per year. (The fecal coliform bacteria produced by beef cattle while grazing is assumed to be delivered directly to pastureland.) The total fecal coliform load from cattle manure application is the sum of the dairy and beef loads.
3. The fecal coliform bacteria available for washoff is then calculated by multiplying the annual fecal coliform produced by the amount applied and available for washoff in each subwatershed in each month (from the cattle manure section of the Manure Application sheet).
4. The monthly total is then divided by the number of days in each month to obtain the daily accumulation rate.

5. Finally, the daily accumulation rate is divided between cropland and pastureland and the portion applied to cropland is divided by the number of acres of cropland in each subwatershed to obtain the daily per acre load of fecal coliform bacteria from cattle manure.

Poultry Litter
The fecal content of the litter is considered here, despite the fact that litter is the combination of manure and bedding. As such, the fecal coliform bacteria produced by chickens and applied to cropland is estimated from the rate of manure production per chicken and the bacteria content of that manure, rather than from the bacteria content of the combined manure and bedding.

The fecal coliform bacteria from poultry litter applied per acre of cropland is determined for each month as follows:

1. The number of chickens in each subwatershed (from the Animals sheet) is multiplied by the daily fecal coliform production rate per chicken (from the References sheet) to obtain the daily poultry fecal coliform production rate.
2. The daily rate is then multiplied by 365 to obtain the amount of fecal coliform produced by chickens per year.
3. The fecal coliform bacteria available for washoff is then calculated by multiplying the annual fecal coliform produced by the amount applied and available for washoff in each subwatershed in each month (from the poultry litter section of the Manure Application sheet).
4. The monthly total is then divided by the number of days in each month to obtain the daily accumulation rate.
5. Finally, the daily accumulation rate is divided by the number of acres of cropland in each subwatershed to obtain the daily per acre load of fecal coliform bacteria from poultry litter.

The total accumulation rate of fecal coliform bacteria from cropland is calculated as the sum of the accumulation rates from wildlife and hog, cattle, and poultry manure applications.

FOREST

-	User Input Required

The wildlife population is the only fecal coliform contributor to forest considered. No user input is required on the Forest sheet. The fecal coliform bacteria produced by wildlife per acre of forest is determined for each month as follows:

1. The total wildlife population of each subwatershed is calculated (acres of forest from the Land Use sheet multiplied by the forest wildlife density from the Wildlife sheet).

2. The total daily fecal coliform bacteria load generated by that population is calculated (acres of forest from the Land Use sheet multiplied by the fecal coliform generated per acre of forest from the Wildlife sheet).
3. The daily per acre accumulation of fecal coliform bacteria from wildlife is calculated by dividing the total load generated by the number of acres of forest in each subwatershed.

BUILT-UP

U	User Input Required

Because of the lack of animal counts and other specific source information for built-up land, literature values are used. Built-up land is broken out into four categories:

- Commercial and Services
- Mixed Urban or Built-Up
- Residential
- Transportation, Communications and Utilities

1. The percentage breakout of these categories is specified by the user in the Built-up sheet. The acres of each built-up category in each subwatershed are calculated by multiplying the total built-up acres (from the Land Use sheet) by the percentage breakouts specified by the user.
2. A daily per acre fecal coliform bacteria loading rate is calculated for each built-up category using literature values. The loading rates provided in Horner (1992) and presented in the References sheet are applied as follows:

Built-up category	**Fecal coliform loading rate (count per acre per day)**
Commercial and Services	Commercial
Mixed Urban or Built-Up	Average of road, commercial, single-family low-density, single-family high-density, and multifamily residential
Residential	Average of single-family low-density, single-family high-density, and multifamily residential
Transportation, Communications and Utilities	Road

3. A weighted average built-up fecal coliform bacteria accumulation rate is calculated for each subwatershed based on the individual built-up land use categories present and their corresponding accumulation rates.

PASTURELAND

-	User Input Required

This sheet calculates the total fecal coliform bacteria applied to each acre of pastureland by month. The sources of fecal coliform bacteria for pastureland are wildlife, cattle and horse manure application, and beef cattle, horse, sheep, and other grazing. No user input is required on the Pastureland sheet. It is assumed that dairy cattle are confined all of the time and their manure is applied to both cropland and pastureland. Beef cattle are assumed to be kept in feedlots or allowed to graze, depending on the season. When they are grazing, a certain proportion of the cattle is assumed to have direct access to streams (as specified on the Grazing sheet.) Beef cattle manure is therefore applied to cropland and pastureland, contributed directly to pastureland during grazing, or contributed directly to streams (referred to by the tool as Cattle in Streams.) Horse manure that is not deposited in pastureland during grazing is assumed to be collected and applied to pastureland. Sheep and "other" animal manure that is not deposited in pastureland during grazing is assumed to be collected and treated or transported out of the watershed and is tabulated in the last column of the Pastureland sheet (FC collected).

Wildlife

The fecal coliform bacteria produced by wildlife per acre of pastureland is determined for each month as follows:

1. The total wildlife population of each subwatershed is calculated (acres of pastureland from the Land Use sheet multiplied by the pastureland wildlife density from the Wildlife sheet).
2. The total daily fecal coliform bacteria load generated by that population is calculated (acres of pastureland from the Land Use sheet multiplied by the fecal coliform generated per acre of pastureland from the Wildlife sheet).
3. The daily per acre accumulation rate of fecal coliform bacteria from wildlife is calculated by dividing the total load generated by the number of acres of pastureland in each subwatershed.

Cattle Manure

The fecal coliform bacteria from cattle manure applied per acre of pastureland is determined for each month as follows:

1. The number of dairy and beef cattle in each subwatershed (from the Animals sheet) is multiplied by the daily fecal coliform production rate per dairy and beef cow (from the References sheet) to obtain the daily dairy and beef cattle fecal coliform production rates.
2. The daily dairy fecal coliform production rate is then multiplied by 365 days to obtain the annual amount of fecal coliform produced by dairy cattle and available for application as manure. The daily beef fecal coliform production rate is multiplied by 365 days minus the days spent grazing (from the cattle section of the Grazing sheet) to obtain the annual amount of fecal coliform produced by beef cattle and available for application as manure.

(The fecal coliform bacteria produced by beef cattle while grazing is assumed to be delivered directly to pastureland; see below.) The total fecal coliform load from cattle manure application is the sum of the dairy and beef loads.

3. The fecal coliform bacteria available for washoff is then calculated by multiplying the annual fecal coliform produced by the amount applied and available for washoff in each subwatershed in each month (from the cattle manure section of the Manure Application sheet).
4. The monthly total is then divided by the number of days in each month to obtain the daily accumulation rate.
5. Finally, the daily accumulation rate is divided between Cropland and Pastureland and the portion applied to Pastureland is divided by the number of acres of pastureland in each subwatershed to obtain the daily per acre accumulation of fecal coliform bacteria from cattle manure.

Horse Manure
The fecal coliform bacteria from horse manure applied per acre of pastureland is determined for each month as follows:

1. The number of horses in each subwatershed (from the Animals sheet) is multiplied by the daily fecal coliform production rate per horse (from the References sheet) to obtain the daily horse fecal coliform production rate.
2. The daily rate is then multiplied by 365 days minus the days spent grazing (from the horse section of the Grazing sheet) to obtain the amount of fecal coliform produced by horses and available for application as manure per year. (The fecal coliform bacteria produced by horses while grazing is assumed to be delivered directly to pastureland; see below.)
3. The fecal coliform bacteria available for washoff is then calculated by multiplying the annual fecal coliform produced by the amount applied and available for washoff in each subwatershed in each month (from the horse manure section of the Manure Application sheet).
4. The monthly total is then divided by the number of days in each month to obtain the daily accumulation rate.
5. Finally, the daily accumulation rate is divided by the number of acres of pastureland in each subwatershed to obtain the daily per acre accumulation of fecal coliform bacteria from the application of horse manure.

Beef Cattle Grazing
The fecal coliform bacteria from beef cattle manure deposited during grazing per acre of pastureland is determined for each month as follows:

1. The number of beef cattle grazing is calculated by multiplying the number of beef cattle per subwatershed (from the Animals sheet) by the fraction of time spent grazing (from the Grazing sheet).
2. The fecal coliform load delivered directly to pastureland is calculated by multiplying the number of cattle grazing by the fraction of time spent in pasture (as opposed to in

streams, from the Grazing sheet) and by the rate of fecal coliform bacteria production per beef cow (from the References sheet).

3. Finally, the daily grazing beef cattle fecal coliform production is divided by the number of acres of pastureland in each subwatershed to obtain the daily per acre accumulation rate of fecal coliform bacteria from beef cattle grazing.

Horse Grazing

The fecal coliform bacteria from horse manure deposited during grazing per acre of pastureland is determined for each month as follows:

1. The number of horses grazing is calculated by multiplying the number of horses per subwatershed (from the Animals sheet) by the fraction of time spent grazing (from the Grazing sheet).
2. The fecal coliform load delivered directly to Pastureland is calculated by multiplying the number of horses grazing by the rate of fecal coliform bacteria production per horse (from the References sheet).
3. The fecal coliform load in manure collected for application is calculated by subtracting the number of horses grazing from the total number of horses and multiplying by the rate of fecal coliform bacteria production per horse (from the References sheet).
4. Finally, the daily grazing horse fecal coliform production is divided by the number of acres of pastureland in each subwatershed to obtain the daily per acre accumulation rate of fecal coliform bacteria from horse grazing.

Sheep Grazing

The fecal coliform bacteria from sheep manure deposited during grazing per acre of pastureland is determined for each month as follows:

1. The number of sheep grazing is calculated by multiplying the number of sheep per subwatershed (from the Animals sheet) by the fraction of time spent grazing (from the Grazing sheet).
2. The fecal coliform load delivered directly to Pastureland is calculated by multiplying the number of sheep grazing by the rate of fecal coliform bacteria production per sheep (from the References sheet).
3. The fecal coliform load in manure collected for disposal is calculated by subtracting the number of sheep grazing from the total number of sheep and multiplying by the rate of fecal coliform bacteria production per sheep (from the References sheet).
4. Finally, the daily grazing sheep fecal coliform production is divided by the number of acres of pastureland in each subwatershed to obtain the daily per acre accumulation rate of fecal coliform bacteria from sheep grazing.

Other Animal Grazing

The purpose of the “other” animal category is to allow you to define an agricultural animal not available in the default information. To use this category, you must be sure to enter the number of “other” agricultural animals in each subwatershed (on the Animals sheet), to enter the time spent grazing (on the Grazing sheet), and to specify a fecal coliform bacteria production rate (on the References sheet). The fecal coliform bacteria from “other” animal manure deposited during grazing per acre of pastureland is determined for each month as follows:

1. The number of “other” animals grazing is calculated by multiplying the number of “other” animals per subwatershed (from the Animals sheet) by the fraction of time spent grazing (from the Grazing sheet).
2. The fecal coliform load delivered directly to pastureland is calculated by multiplying the number of “other” animals grazing by the rate of fecal coliform bacteria production per “other” animal (from the References sheet).
3. The fecal coliform load in manure collected for disposal is calculated by subtracting the number of “other” animals grazing from the total number of “other” animals and multiplying by the rate of fecal coliform bacteria production per “other” animal (from the References sheet).
4. Finally, the daily grazing “other” animal fecal coliform production is divided by the number of acres of pastureland in each subwatershed to obtain the daily per acre accumulation rate of fecal coliform bacteria from “other” animal grazing.

The total accumulation rate of fecal coliform bacteria from pastureland is calculated as the sum of the accumulation rates from wildlife, cattle and horse manure applications, and beef cattle, horse, sheep and “other” grazing.

CATTLE IN STREAMS

-	User Input Required

This sheet contains information related to the direct contribution of beef cattle fecal coliform bacteria to streams. This contribution can be represented as a point source in HSPF, which requires input of a flow rate (cubic feet per second, or cfs) and a fecal coliform bacteria loading rate (count per hour). No user input is required on this sheet. It is assumed that only beef cattle have access to streams when grazing. The fraction of grazing time spent in streams is specified on the Grazing sheet.

1. The number of beef cattle in streams is calculated by multiplying the total number of beef cattle (from the Animals sheet) by the fraction of time spent grazing and the fraction of grazing time spent in streams (from the Grazing sheet).
2. The fecal coliform bacteria loading rate (count/hr) is calculated by multiplying the number of beef cattle in streams by the fecal coliform production rate per beef cow (from the References sheet.)
3. The beef cattle waste flow rate is calculated by multiplying the number of cattle in streams by the waste production rate per beef cow (from the References sheet) and an assumed beef cattle waste density of 62.4 pounds per cubic foot.

SEPTICS

U	User Input Required

This sheet contains information related to the contribution of failing septic systems to streams. The direct contribution of fecal coliform from septics to a stream can be represented as a point source in the model, which requires input of a flow rate (cfs) and a fecal coliform bacteria loading rate (count/hr).

To estimate the contribution of fecal coliform bacteria from failing septic systems, the number of septic systems, the number of people served by septic systems, and the estimated rate of septic system failure in the study area must be entered. Population and septic tank data can be retrieved from the U.S. Census Bureau web site (http://venus.census.gov/cdrom/lookup). For example, county level populations and septic tank information can be retrieved from this web site as follows:

- Under "Choose a Database to Browse" select STF3A
- On the next screen, click on "Go to level State--County" and choose a State from the list below, and then click on "Submit."
- On the next screen, choose "Retrieve the areas you've selected below" and select a county on the list, and submit.
- Select "Choose TABLES to retrieve" and submit.
- From the list of tables, select "P1" and "H24" and submit
- Select the format for the retrieval (e.g., HTML)
- The information displayed will include a county level summary of population and of housing units with public sewer, septic tank or cesspool, or other.

The estimated rate of septic system failure in the area of interest should be estimated based on local knowledge. From the preceding information, the average number of people served by each septic system, number of failing septic systems, and density of failing septic systems in the study area are calculated.

1. The number of failing septic systems in each subwatershed is calculated by multiplying the total area of each subwatershed (from the Land Use sheet) by the density of failing septic systems.
2. The number of people served by failing septic systems in each subwatershed is calculated by multiplying the number of failing septic systems by the average number of people served by each septic system.
3. The failing septic system flow rate is calculated by multiplying the number of people served by failing septic systems by an assumed daily waste flow of 70 gallons per person.
4. The fecal coliform bacteria loading rate from failing septic systems is calculated by multiplying the failing septic system flow rate by an assumed fecal coliform bacteria

concentration of 10,000 counts per 100 mL of waste flow. Note that any of the assumed values can be updated to represent more appropriate site-specific information.

ACQOP&SQOLIM (FOR LAND USES)

-	User Input Required

This sheet summarizes HSPF input parameter values calculated based on designations made throughout the spreadsheet. It contains values for model inputs ACQOP (or MON-ACCUM if monthly) and SQOLIM (or MON-SQOLIM if monthly). These parameters represent the rate of fecal coliform accumulation and the maximum storage of fecal coliform bacteria on land uses.

1. The values for ACQOP are simply the total fecal coliform bacteria accumulation rates from each land use sheet (Cropland, Pastureland, Forest, and Built-up).
2. The value for SQOLIM is derived using the following die-off equation from Horsley & Whitten (1986):

$N_t = N_0(10^{(-kt)})$ where: N_t = number of fecal coliforms present at time t
N_0 = number of fecal coliforms present at time 0
t = time in days
k = first order die-off rate constant. Typical values for warm months = 0.51/day and for cold months = 0.36/day

In the above equation, N_0 is the count of fecal coliforms applied per acre per day (MON-ACCUM). N_t is the count of fecal coliforms applied on a given day that survive for some number t of days. The maximum buildup of fecal coliform (MON-SQOLIM) is equal to the sum of the fecal coliforms applied on a given day and of the fecal coliforms that were applied on previous days and have survived until that day. When this calculation is done, the maximum buildup is estimated to be approximately 1.5 times the daily buildup rate during warm months (die-off rate of 0.51/day) and 1.8 times the daily buildup rate for colder months (die-off rate of 0.36/day). Warmer months are assumed to be April through September; colder months are October through March. A buildup limit of 1.8 times the daily buildup rate is assumed for nonmonthly varying SQOLIM (Forest and Built-up).

TRANSFERRING DATA FROM THE BACTERIAL INDICATOR TOOL TO WINHSPF

Information contained in three sheets of the Bacterial Indicator Tool can be transferred to WinHSPF. These sheets are Cattle in Streams, Septics, and ACQOP&SQOLIM (for land uses). The information in the Cattle in Streams and Septics sheets are input into the model as point sources. Each sheet contains the fecal coliform loading rate (in count/hr) and flow rate (in cfs) for each subwatershed. The Cattle in Streams loading and flow rates vary monthly, while the septic rates are constant. See “Detailed Functions - Points Sources” of the *WinHSPF Version 2.0 Manual* (USEPA, March 2001) found in the “\basins\docs” folder for detailed instructions on how to incorporate point sources into WinHSPF.

The information contained in the ACQOP&SQOLIM (for land uses) sheet should be input into WinHSPF using the Input Data Editor. See “Detailed Functions - Input Data Editor” of the *WinHSPF Version 2.0 Manual* (USEPA, March 2001) for detailed instructions on using WinHSPF’s Input Data Editor. The constant values for forest and built-up land should be input using the *ACQOP* and *SQOLIM* columns in the PERLND\PQUAL\QUAL-INPUT and the IMPLND\IQUAL\QUAL-INPUT tables.

The monthly varying values for cropland and pastureland should be input using the *MON-ACCUM* and *MON-SQOLIM* tables under PERLND\PQUAL\ and IMPLND\IQUAL\.

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